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MEDICAL
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MEDICAL RADIOGRAPHIC TECHNIC

Prepared by

The Technical Service Department of
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under the
editorial supervision of

GLENN W. FILES, DIRECTOR

in association with these Contributors

JOHN R. ARMSTRONG
GEORGE A. ASHWORTH
CHARLES H. BUCKINGHAM
HERBERT R. CASE
GILBERT O. CLASON
FRANK C. COOKE
FRANCIS G. DAVIS
MORTON D. FAGAN
KENNETH E. HALL
FREDERICK H. LYNK
HAROLD O. MAHONEY
JEANNE L. MINNEMA
CHARLES B. MINNICH
JOSEPH F. RODERICK
ARTURO A. SILVA
ARTHUR R. SWANSON
JOHN B. THOMAS

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Preface

As I see it now, this book is somewhat like Topsy—"It just grew and grew."

In the beginning, members of the Technical Service Department wanted a handbook for their own guidance in formulating a standard method of teaching x-ray operative procedure. These men were brought together for the purpose of deciding on an outline of class procedure, which, with minor changes, could and would be used by all of us.

It is only natural that certain variations in the teaching of any subject depends upon the individual; nevertheless, the fundamental principles, based upon facts, is the baseline of all instruction.

As the ideas grew in number (and in scope), it was finally decided that instead of merely having an interdepartmental notebook for instructors, it would be more worthwhile to make our information available to all. So, from such a beginning, this reference book is made available.

Our greatest appreciation is expressed to the organization which has provided us with the opportunities, facilities and finances for making this effort possible.

It is a book written by technicians for technicians, an accumulation of material based upon facts now available which have proven to be an aid in producing a "better end result" and the reasons why.

G. W. F.

14Mar45 Brown 5 10 Physics

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Mr. John R. Armstrong and Miss Idylle Saffran compiled the index.

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G. W. F.

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MEDICAL RADIOGRAPHIC TECHNIC

CHAPTER 1

Fundamental Electrical Concepts

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The basis for the generation of x-rays is essentially electrical in nature since the energy input to the x-ray tube is electrical energy. For this reason no clear understanding of the controlling factors can be had without some acquaintance with such fundamental electrical concepts as electromotive force, resistance, direct current, alternating current, transformers, capacitance, etc.

Electric Potential and Current

An electric current will flow through a circuit or through two points of a circuit between which an electric potential exists. The current of electricity is assumed to be a movement of negatively charged particles called electrons. Their occurrence may be as free electrons within the structure of the material of which the conductors are composed, or as bound constituents of the atom itself. The electric potential may be established by a variety of agents, among which are friction, chemical action, pressure, heat, and magnetic induction, the last of these being of particular interest in subject matter to follow. The effect of the electromotive force, due to the difference of potential, is to cause an electric current to flow which is directly proportional to the electromotive force and inversely proportional to the impeding elements in the circuit. The general nature of the electromotive force is the same whatever the agency by which it is produced, but the specific characteristics of the resultant current will depend on the form of its origin. This relationship may be expressed as

$$i = \frac{e}{z}$$

in which i = instantaneous value of the electric current
e = instantaneous value of the electromotive force
z = a factor expressing the impeding forces

The potential difference produced by contact of dissimilar substances, thermo-electric action, friction between dissimilar substances, and chemical action, is continual and constant, assuming that activity is proceeding at a constant rate. In the case of a simple voltaic cell, as shown in Figure 1, there will be a voltage established at the terminals which will be constant as long as the surfaces in the solution are pure and uncontaminated so that no secondary chemical action will take place. If an electrical circuit is completed externally, as shown in Figure 2, an electric current will flow in the direction indicated from the positive terminal through an indicating meter, through the remainder of the circuit symbolically represented by the resistance R and back to the source. The current will continue to flow as long as the circuit is complete and its direction and magnitude will remain constant.

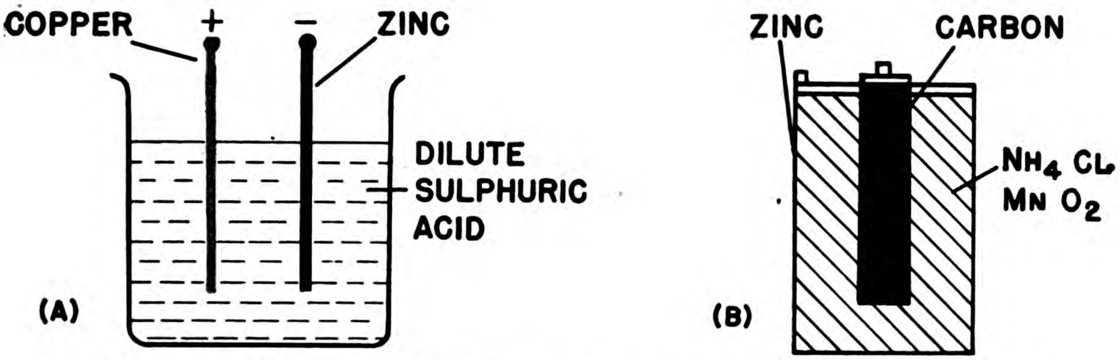

FIG. 1. Electro-chemical sources of electromotive force showing (a) simple voltaic cell and (b) "dry" cell.

Such a current is known as a *direct current* and is represented in Figure 3, in which units of current are plotted against time. This graphic representation is a convenient one since it indicates the direction of magnitude of the current at any time, T. The current I is defined as the rate of flow of electricity

$$I = \frac{Q}{T}$$

in which Q = quantity of electricity in coulombs
I = current in amperes
T = time in seconds

As indicated above, the relationship of the intensity of the current to the electromotive force producing it is linearly proportional. For a direct current circuit, Ohm's law is

$$I = \frac{E}{R}$$

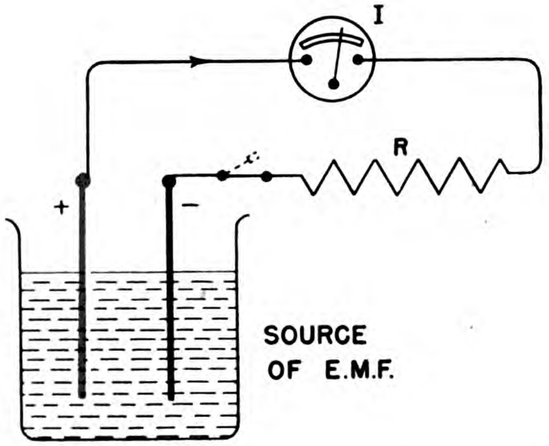

FIG. 2. Complete electrical circuit showing conventional direction of current flow.

in which I = current in amperes
E = electromotive force in volts
R = a constant of proportionality termed resistance (ohm)

The term R is a measure of the characteristic property of the circuit which resists the flow of current. It depends on the material which forms the electrical path, the length of the path, and its cross-sectional area. The formula is

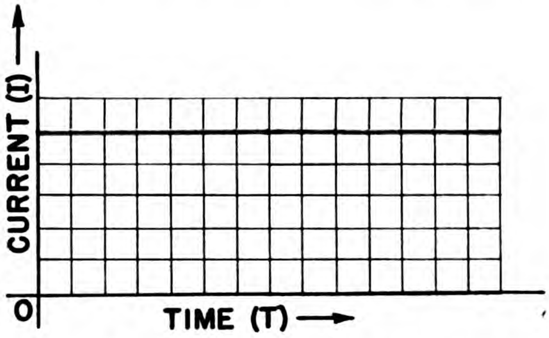

FIG. 3. Relation of current to time in a constant current circuit.

$$R = \rho \frac{L}{A}$$

in which R = resistance (ohms)
L = length of circuit
A = cross-sectional area
ρ = resistivity of the material forming the circuit

The nature of ρ is important. Materials differ widely in their ability to conduct electricity, varying from practically non-conductors like glass and mica to excellent conductors like copper and silver. The non-conductors offer very high resistance to the flow of electricity and are called insulators, though it is recognized that such a classification is relative, not absolute. The best conductors offer some resistance to the flow of electricity and the best insulators under certain conditions permit the flow of some electricity. The question of insulation and conduction is further complicated by the effects of temperature, pressure, surface conditions, and even the magnitude of the applied voltage, so that some materials may be reasonably good insulators under a given set of conditions, but very poor insulators under another.

Electromotive Force by Magnetic Induction

One source of electromotive force which is of particular importance in understanding the principle of the alternating current transformer is that of magnetic induction. If a wire is moved across a magnetic field, a potential difference will be produced between the end points of the wire. Figure 4 illustrates the principle and the direction of tne induced electromotive force for a conductor moving downward in a left to right field. The electromotive force is proportional to the strength of the magnetic field, the length of the wire, and the velocity of the conductor. The formula is:

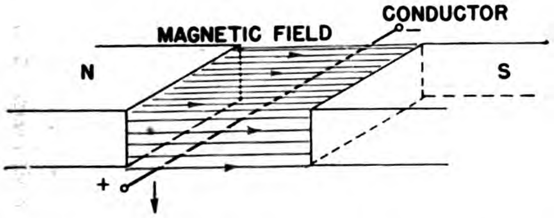

FIG. 4. Electromotive force produced by magnetic induction in a conductor moving across a field.

$E = kBlv$ volts

in which B = density of the magnetic flux (Gausses)
l = length of the conductor (centimeters)
v = velocity of the conductor (centimeters per second) with respect to the field
$k = 10^{-8}$

Conversely, if the magnetic field is moving with respect to the conductor, there will be an electromotive force produced in the conductor, its direction dependent upon the direction of the motion of the field and of the magnetic lines of force.

If both field and conductor are stationary, and if the magnetic field changes in intensity, there will be an electromotive force induced in the conductor which is proportional to the rate at which the field is changing. In such a case,

$$E = K \frac{\varphi_2 - \varphi_1}{t}$$

in which φ_1 = original magnetic flux
φ_2 = final magnetic flux
t = time over which the change takes place
E = average induced voltage
K = constant

The Heating Effect of an Electric Current

The current I flowing in the simple circuit of Figure 2 manifests itself by an evolution of heat in all parts of the circuit which is proportional to the square of the current and to the resistance of the portion of the circuit being considered. In the resistance R, for instance, $P = I^2 R\, 10^7$ ergs per second. If the current continues to flow for a time, T, the energy supplied to the resistance will appear as heat, equal to $W = I^2 RT$ Joules. This expression is known as Joule's law, and may conveniently be written $W = 0.24\ I^2\ RT$ calories, by introduction of a mechanical equivalent of heat, 4.19×10^7 ergs = 1 calorie. Use will be made of Joule's law in a later section for computation of the total energy input into the anode of an x-ray tube.

Magnetic Effect of an Electric Current

An electric current flowing through a conductor will produce a magnetic field in the vicinity of the conductor. The lines of magnetic force will surround the wire in concentric circles as shown in Figure 5, which lie in planes perpendicular to the axis of the conductor, and which have their centers on this axis. If the conductor is wound in the form of a solenoid, the magnetic intensity is increased with the field distribution as shown in Figure 6. The lines of force are similarly distributed in three dimensions of space, each of them being closed curves, linked with one or more turns of the coil in which the current is flowing. The magnetic intensity within the solenoid is given by:

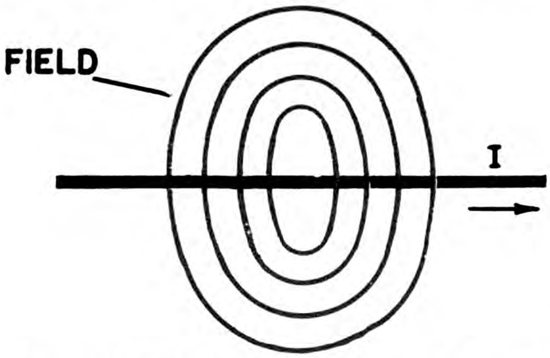

FIG. 5. Lines of magnetic force surrounding a wire carrying an electric current.

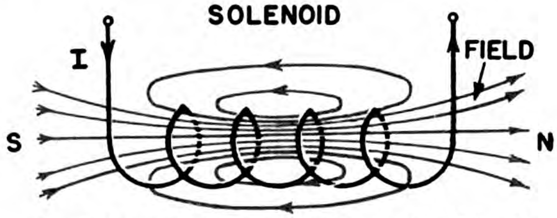

FIG. 6. Magnetic field surrounding a solenoid in air.

$$H = \frac{4\pi NI}{10}$$

in which H = magnetic field intensity (gilberts per centimeter)
N = number of turns per centimeter
I = current (amperes)

If an iron core is introduced within the solenoid, the field intensity will be greatly increased since the iron will become magnetized by induction and will add a magnetic flux to the original, and the field will be changed as shown in Figure 7. Within the core, the number of lines of force per unit area or magnetic flux density, is greatly increased, the factor for a good grade of magnetic iron being 3,000 times that for air. This characteristic is called the permeability of the magnetic medium, and is defined as:

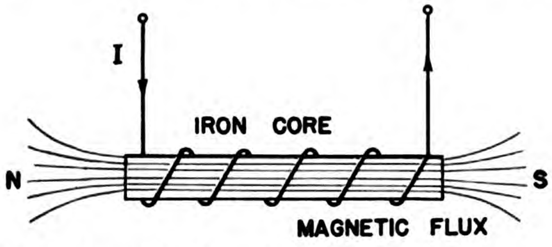

FIG. 7. Magnetic field around a solenoid with an iron core.

$$\mu = \frac{B}{H}$$

in which μ = permeability

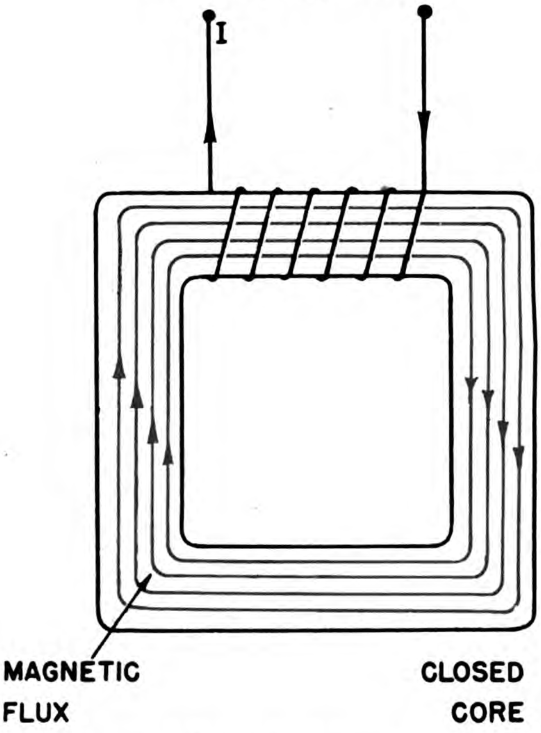

FIG. 8. Magnetic field in a closed iron core produced by current flowing through a solenoid.

H = magnetic field intensity
B = flux density

In Figure 7, the magnetic circuit is completed in air which has a comparatively high magnetic reluctance. Forming the solenoid over a closed iron core, as shown in Figure 8, the flux density is still further increased since the magnetic lines of force have a complete circuit in a material of good magnetic characteristics. The relation of the electric current I to the magnetic flux φ which it produces is given by:

$$\varphi = \frac{4\pi}{10} \frac{NI}{L} \mu A$$

in which φ = flux (maxwells)
N = number of turns in the coil
I = current (amperes)
L = mean length of core (centimeters)
A = cross-section of the core (centimeters^2)
μ = permeability of the core.

Electromotive Force of Self-Induction and Inductance

It was shown earlier that if the magnetic field changes in intensity, there will be an electromotive force induced in the conductors linked by the field which is proportional to the rate at which the field is changing. In the case of the coil shown in Figure 8, an electromotive force will be induced in each turn of its winding by the changing flux which links its turns. As a result, a voltage will be produced across its terminals in an opposite direction to that which is applied from an external source in order to produce the original flux. This electromotive force is expressed as:

$$E = -N \frac{\alpha\varphi}{\alpha t} 10^{-8} \text{ volts}$$

and is known as an electromotive force of self-induction.

This characteristic of the coil, which is responsible for the induced electromotive force, is called its inductance, and is measured in henries, which is defined as that inductance which, when a current is changing at the rate of one ampere per second, will produce an induced electromotive force of one volt. Inductance can be considered also in terms of the magnetic flux which is produced by the current flowing through the coil. It is then defined as the flux linkages per ampere of current producing the flux:

$$L = \frac{\text{flux linkages}}{\text{current}} 10^{-8} \text{ henries}$$
$$= \frac{N\varphi}{I} 10^{-8} \text{ henries}$$

Capacitors

The ability to store electricity is a characteristic of certain combinations of conductors and insulators which are called capacitors. Whenever an insulator, usually called a dielectric, separates two conductors between which a difference of potential can exist, a quantity of electricity may be stored in the combination which is a function of the area of the conducting plate, the space between them, and the potential difference between them. Figure 9 shows such an arrangement. Applying a voltage between the plates will cause an electric charge to flow into them which, for the case shown, will cease when the poten-

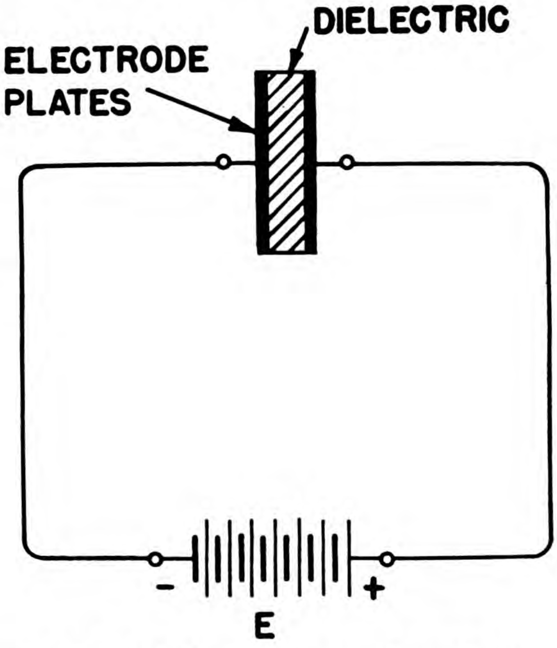

FIG. 9. Electric circuit showing capacitor and direct current source of electromotive force.

tial of the plates is the same as the potential of the charging source. The charge stored in a capacitor is given by the equation:

$$Q = C\,E$$

in which Q = charge in coulombs

C = capacitance in farads

E = potential difference between the plates in volts

Since the current changes with time, it is equal at any instance to the rate of change of the charge. This rate of change with respect to time is mathematically expressed as:

$$I = \frac{dQ}{dt} = C\frac{dE}{dt}$$

For a pair of parallel plates, the capacity in microfarads is given by the equation:

$$C = 0.08842\,K\frac{A}{d}$$

in which A = area of the plate (centimeters)

K = a constant called the dielectric constant which is a function of the material separating the plates. For air, K = 1.

Alternating Current

Thus far in consideration of fundamental electrical concepts, the current has been unidirectional and either constant in magnitude or varying in intensity with time. There is another kind of current which is of very great importance in the theory of x-ray generation and, in particular, the power supply to the x-ray tube. This is *alternating current* which is defined as one which reverses its direction at regularly recurring intervals, most generally with the positive and negative portions symmetrical in shape and area when instantaneous values of current are plotted against time. An understanding of the nature of alternating current can best be obtained by examining the principle of the alternating current electrical generator, the device in which an alternating current is produced.

Figure 10 illustrates the basic principle of an alternating current generator. A loop of wire is made to rotate in a magnetic field which passes from pole N to pole S, produced by the passage of direct current through field coils wound on the poles. The ends of the coil are connected to conducting rings insulated from one another upon which stationary contacts, A and B, complete the electrical circuit to the terminals of the machine.

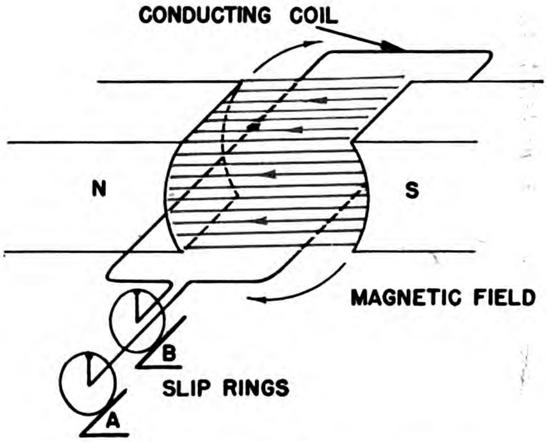

FIG. 10. The basic principle of an alternating current generator.

The direction of the current in the wires will be at right angles to the direction of the magnetic lines and the direction of motion, usually expressed by Fleming's rule.

If the thumb, forefinger, and middle finger of the right hand are perpendicular one to another and the thumb is pointed in the direction of motion of the wire relative to the field, the forefinger in the direction of the magnetic lines of force, then the middle finger will point in the direction of the induced voltage. In Figure 10, an electromotive force will be induced in the wire passing under the N pole in a direction away from the reader, while for the wire passing under the S pole, the direction will be toward the reader. The electromotive force in the conductors A and B forming opposite sides of the coil add together in such a direction that A is the positive terminal and B is the negative terminal when the coil is in the position shown. Now consider the coil rotated half a revolution or 180°: conductor B is then under the S pole and A is under the N pole. The electromotive force reverses and B is the positive terminal with A the negative. The polarity thus reverses itself twice for each revolution of the coil.

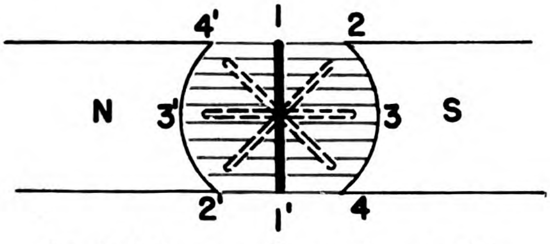

Fig. 11. Reference position of plane of coil in the magnetic field.

The magnitude of the generated voltage is proportional to the rate of change of the magnetic flux through the coil. In Figure 11, when the coil is in position 1, the flux enclosed is a maximum, but the rate at which the number enclosed is changing is zero. Thus the induced voltage is zero. In position 3, similar to that of Figure 10, the flux enclosed is a minimum but the rate at which it is varying is a maximum, so the induced voltage is a maximum. In position 2 the voltage is some intermediate value depending on the angle between the plane of the coil and the plane of the magnetic lines. It can be shown that the rate at which the flux linkages change in a uniform magnetic field cut by a rotating loop conductor is a sine function[1] of the angle through which the coil has passed, beginning from position 1. Figure 12 shows the variation of φ, the enclosed flux, with time and the resultant induced voltage E.

It is not the magnitude of the enclosed flux which determines the voltage, but the *rate* at which it is changing as the coil rotates clockwise from the original position. With the coil in position 1, the voltage generated is zero. It increases until position 3 is reached at which it is a maximum, the angle traversed being 90°. Then the voltage decreases in magnitude until it reaches

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[1] The sine of an angle is the ratio b/c so that C sine α becomes the projected length of the hypotenuse c, in the direction of b.

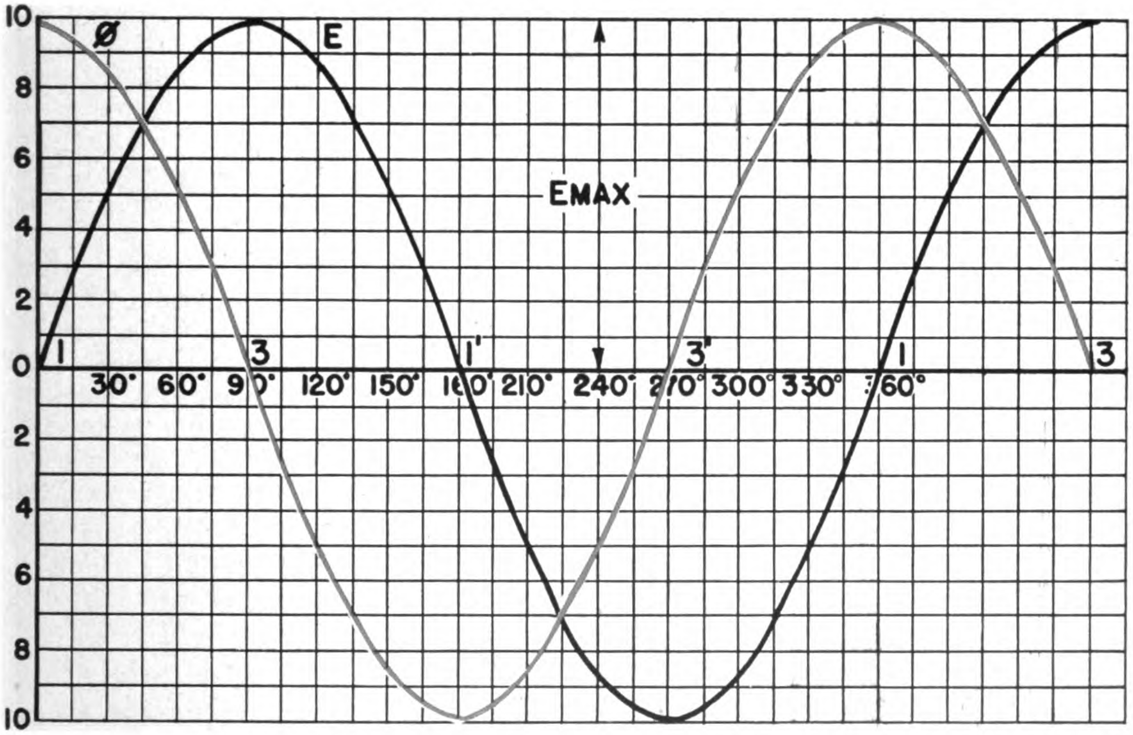

Fig. 12. Variation of flux and induced electromagnetic force with degrees rotation (i.e., time).

zero with the coil perpendicular to the field position 1′; similar to position 1 but with the coil sides reversed. The angular change is 180°. The voltage then increases, but with reversed polarity until a position 3′ is reached, at which it is a maximum, the direction of the induced voltage being opposite to that in position 3. With continued rotation, the cycle of changes repeats itself.

The electrical current produced in the manner described is known as an *alternating current* and is defined as one whose direction reverses at regularly recurring intervals, most generally with successive half waves 1 to 1′ of Figure 12 of the same shape and area when instantaneous values of current are plotted against time.

A cycle is one complete set of positive and negative values of an alternating current.

The frequency is the number of cycles through which it passes per second.

The sine wave is the simple alternating wave shown in Figure 12, for which the changes with time are expressed in terms of a function of the maximum value E_{max} and the angle α as:

$$e = E_{max} \sin \alpha \text{ (volts)}$$
$$\text{or } i = I_{max} \sin \alpha \text{ (amperes)}$$

The table, Figure 13, gives instantaneous values for various angles, measured from the position of minimum induced voltage.

Angle α	*e*
0°	0
30°	$0.50\ E_{max}$
60°	$0.866\ E_{max}$
90°	$1.00\ E_{max}$
120°	$0.866\ E_{max}$
150°	$0.50\ E_{max}$
180°	0
210°	$-0.50\ E_{max}$
240°	$-0.866\ E_{max}$
270°	$-1.00\ E_{max}$
300°	$-0.866\ E_{max}$
330°	$-0.50\ E_{max}$
360°	0

FIG. 13. Table showing instantaneous values of induced electromotive force for various positions of the coil measured from the position of minimum induced voltage.

Since the operation of electrical devices may involve no rotation, it is necessary to express the equation above as a function of time or frequency of the alternating current. If the coil is rotating with a uniform angular velocity w,

$$\alpha = wt$$

If f is the frequency,

$$w = 2\pi f, \text{ since one complete revolution is } 2\pi \text{ radians.}$$

Then,

$$\varepsilon = E_{max} \sin(2\pi\, ft)$$

The average value of the ordinate of a wave is the area of a half-cycle divided by the length of its base, in suitable units. For a sine wave, this is

$$E_{av} = \frac{2}{\pi} E_{max} = 0.636\ E_{max}$$

Of great importance also is the effective value of an alternating current, or its comparison to a direct current with reference to energy content. This figure is obtained by determining the square root of the average of the squares of the instantaneous values for a complete cycle. This is called the root-mean-square value and for a sine wave is

$$E_{r.m.s.} = \frac{1}{\sqrt{2}} E_{max} = 0.707\ E_{max}$$

Since, for power calculations, the effective values are always used instead of average or maximum values, ammeters and voltmeters for alternating current are calibrated to read these values, and the subscript root-mean-square is understood.

The alternating current of sine wave form is the basis for electrical design and calculation and may, in most cases, be assumed to represent current and voltage waves in electrical circuits. It must be recognized, however, that any departures from the theoretical conditions assumed or the presence of distortions in the magnetic field, or of losses in the circuit itself may modify the wave shape to a considerable extent necessitating special methods of approach.

The Alternating Current Transformer

In the previous discussion of electricity and magnetism, two conclusions were established:

1. An electric current produces a magnetic

field in the vicinity of the circuit in which it flows.

2. An electromotive force is induced in a conductor when the magnetic field enclosed by the conductor is changing in intensity, the magnitude of the induced electromotive force being proportional to the rate of change of magnetic flux.

It was shown on page 5 that an electromotive force is induced in a conductor when the magnetic field enclosed by the conductor is changing in intensity, the magnitude of the induced electromotive force being proportional to the rate of change of magnetic flux. These principles can be combined in a manner shown in Figure 14. An iron core has wound on it two coils insulated from the core and from each other.

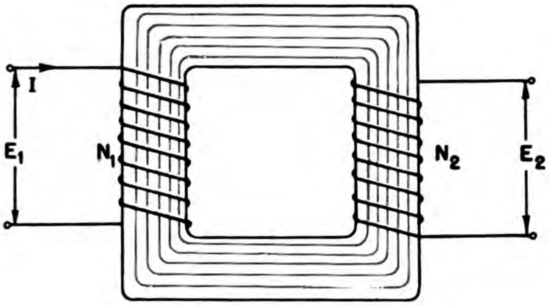

FIG. 14. The basic principle of the transformer—electromotive force produced in one coil as a result of current flowing through another.

One of these coils carries an electric current produced by an external electromotive force. The current I flowing through the coil No. 1 establishes a magnetic flux in the iron core which is proportional to the intensity of the current, the number of turns N_1 in the coil, the cross-sectional area of the core, its permeability and the inverse of its mean length. The flux so produced passes through the magnetic circuit and is linked by coil No. 2. A change in any of the factors affecting φ will produce a change in flux which will according to the law of magnetic induction, establish an electromotive force across the coil given by

$$E_2 = N_2 \frac{d\varphi}{dt} 10^{-8} \text{ (volts)}$$

in which E_2 = induced electromotive force across coil No. 2 (volts)
N_2 = number of turns in coil No. 2
$\frac{d\varphi}{dt}$ = rate of change of flux with time

E_2 is an electromotive force produced in the second coil as a result of mutual induction by the magnetic field, linking the first and second and established by the current flowing in the first coil. If the coil is connected to an external circuit, a current will flow which is proportional to the magnitude of the potential difference across the terminals. Neglecting losses due to heating of the windings and stray magnetic leakage, the power delivered by the second coil (secondary winding) will be equal to that delivered to the first coil (primary).

Since the magnetic flux is common to both coils, the voltage per turn induced in each must be the same. The voltage applied to the primary coil can be considered equal to the voltage of self-induction of the primary, and the terminal voltage of the secondary can be considered equal to the secondary induced voltage. Then,

$$\frac{E_1}{N_1} = \frac{E_2}{N_2}$$

in which E_1 = primary voltage
N_1 = primary turns
E_2 = secondary voltage
N_2 = secondary turns

or

$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

which indicates that the primary and secondary voltages are in proportion to the number of turns of each.

A device of this type is known as a transformer since with it electrical power at any given voltage can be converted into power at any desired voltage by proper selection of the turn ratio.

Assume that the transformer of Figure 14 is supplied with an alternating sine wave voltage of the characteristics previously described, varying cyclically in magnitude and direction. The magnetic flux produced will have a variation curve similar to that for the applied voltage, satisfying the conditions for electromagnetic induction by changing flux linkages through a coil, and giving rise to an induced voltage in coil 2 of value

$$E_{max} = 2\pi fN_1\varphi_{max}10^{-8} \text{ (volts)}$$

The same equation applies to the induced voltage in coil 1, which is equal and opposite to the applied voltage E_1. Therefore the mutual flux in a transformer is determined by the frequency, the number of turns in the primary winding, and the impressed voltage. The secondary induced voltage is determined by the mutual flux and frequency, both of which are fixed by the primary, and the number of turns in the secondary. The voltage induced per turn in each winding must be the same. Then, repeating equation

$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

$$\text{and } \frac{I_1}{I_2} = \frac{N_2}{N_1}$$

the ratio of primary voltage to secondary voltage is practically equal[1] to the ratio of the number of turns on each, the ratio of primary current to secondary current is the inverse ratio of the number of turns on each, and the transformer, then, is a device for converting electrical power at one voltage to approximately the same amount of power at another voltage.

A *step-down* transformer is one in which the output voltage is less than the input voltage; a *step-up* transformer is one in which the reverse is true. The ratio of primary voltage to secondary voltage is called the ratio of transformation and is very nearly the same as the turn ratio.

Figure 15 is a specialized type of step-down transformer for heating the filament of an x-ray tube used in radiography. The filament requirements for the greatest emission which is likely to be used is 10 volts and 5.5 amperes so that with a ratio of transformation of 16:1 and some means of primary voltage control, a rheostat, the power supply of 230 volts and 60 cycles is suitably transformed. The primary winding has 800 turns of wire sufficiently heavy to carry 2 amperes and the secondary winding has 50 turns of wire with 5 times the cross-sectional area so that 5.5 amperes is a conservative current.

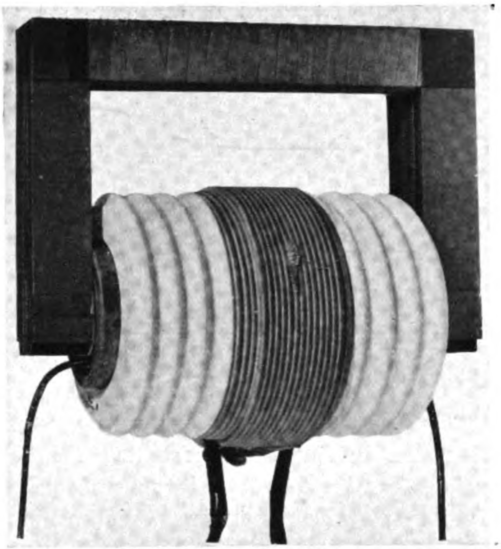

FIG. 15. Step-down transformer for filament heating with high-voltage insulation between primary and secondary.

A very important characteristic of an x-ray filament transformer is the high insulation required between the primary and secondary windings. The potential of the cathode side of the x-ray tube with respect to the primary winding is half the voltage across the x-ray tube in practically all circuits. Thus, a tube operating at 80 kilovolts peak will have a potential difference of 40 kilovolts peak to ground at each terminal. Since the secondary of the filament transformer is electrically connected to the cathode, and the primary is only a few hundred volts from ground potential, the two windings must be electrically insulated for high voltage. Thus, although the transformer delivers a low voltage, it is a high voltage insulation transformer and the windings must be well spaced. The entire unit is usually immersed in a special insulating oil of high dielectric strength.

Figure 16 is a step-up transformer used for the high voltage supply of an x-ray generator. The output of this particular transformer is 100 kilovolts peak at 100 milliamperes, the primary

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[1] They are the same to within 2 per cent or 3 per cent in a well-designed transformer so that the discrepancy can be disregarded in an elementary discussion.

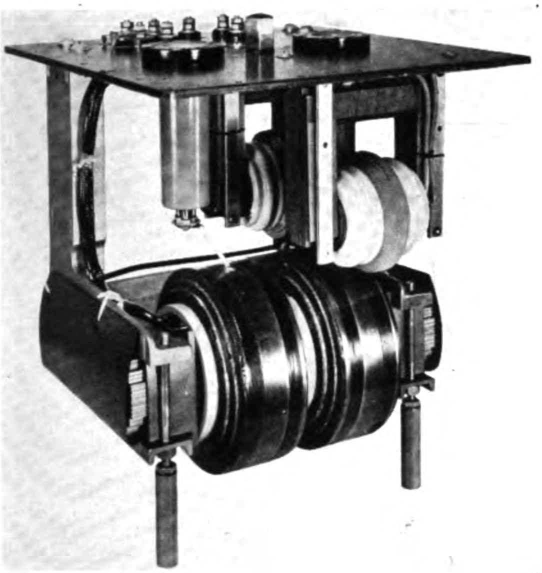

Fig. 16. Step-up transformer designed for 100 kilovolts peak and 100 milliamperes.

power being supplied at 230 volts, 60 cycles. With a ratio of transformation of approximately 1:300 and some means of primary voltage control, it is possible to obtain any desired secondary voltage from 20 kilovolts peak to 100 kilovolts peak. The insulation problem is obviously an important one, since the potential across the secondary may be as high as 100 kilovolts peak.

Inasmuch as the center of the secondary winding is grounded, the voltage at each end with respect to the primary winding or the core of the transformer will, in the unit shown, be half the total or a maximum of 50 kilovolts peak. As in the case of the filament transformer, insulating oil is used as a dielectric surrounding the entire assembly.

The Autotransformer and Voltage Compensator

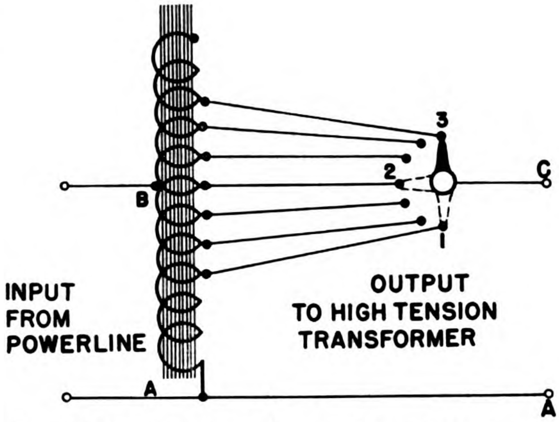

Fig. 17. Elementary circuit diagram of an autotransformer.

The voltage supplied to the x-ray tube is controlled on the primary side of the high tension circuit through an autotransformer. As shown in Figure 17, such a device consists of a single winding, part of which is used both as secondary and primary, the two circuits being electrically connected. The section corresponding to the primary winding is between the points A and B, connected to the incoming power supply. The section corresponding to the secondary is between the points A and C and is variable from position 1 of the selector switch for the minimum to position 3, the maximum number. Since the voltage ratio of the input and output is the same as the respective number of turns, the autotransformer is a step-down device when the selector switch is at any point between 1 and 2, and a step-up transformer at any point between 2 and 3. By providing a large number of connections to the autotransformer winding, it is possible to obtain sufficiently small voltage increments on the output side to provide 1 kilovolt peak steps on the high tension transformer secondary. Figure 18 is a diagram of an autotransformer used on a 200 milliampere x-ray generator for diagnostic application. By manipulating the control knob C, which is mechanically interlocked with a changeover switch D to provide an increased number of turns after control C has made one complete excursion, 100 steps of volt-

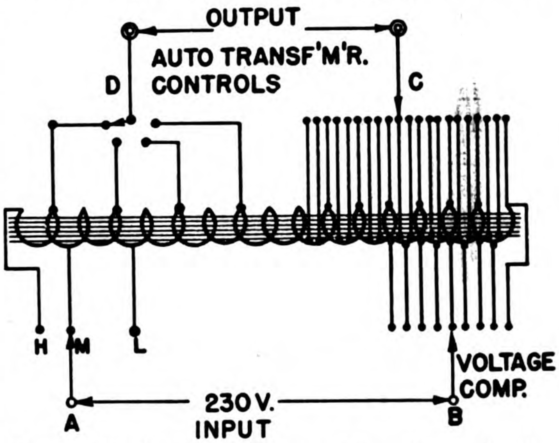

Fig. 18. Circuit diagram of an autotransformer showing refinement for voltage compensation.

age control are obtained. The total number of turns approximates 200.

Selector switch B is a device which is used to maintain the input voltage at a fixed value despite variations in the supply line voltage and which is called the voltage compensator. A voltmeter is connected across a fixed portion of the autotransformer and, by means of the compensator control, the voltmeter pointer is set to a definite mark on the dial which corresponds to the correct voltage for the reproduction of calibration conditions. The taps H, M, and L further extend the range of line voltage compensation. Connection A is made to tap H if the line voltage is from 260 to 240 volts, to tap M from 240 to 220, and to tap L from 220 to 200 volts so that, in connection with the compensator control B, the total range of voltages that can be compensated for extend from 200 to 260 volts.

A typical autotransformer is illustrated in Figure 19. The contact studs brought out from the winding in the region of C, Figure 18, are clearly shown in circular arrangement together with the auxiliary switch D, which extends the range of C. It will be noted that the transformer consists of a single winding with low voltage insulation to the iron core in contrast to the much greater insulation space provided for the secondary windings of both the filament and high tension transformers. Since the autotransformer is not more than several hundred volts from ground potential, it can be mounted as part of the x-ray control apparatus on a panel or in a cabinet easily accessible to the operator. The control knob C is movable over an indicating plate bearing numbers corresponding to the autotransformer taps. Since the autotransformer controls the voltage applied to the primary of the high-tension transformer and this in turn determines the secondary potential applied to the x-ray tube, it is possible to calibrate the apparatus in terms of autotransformer settings for any desired tube voltage at any specified current.

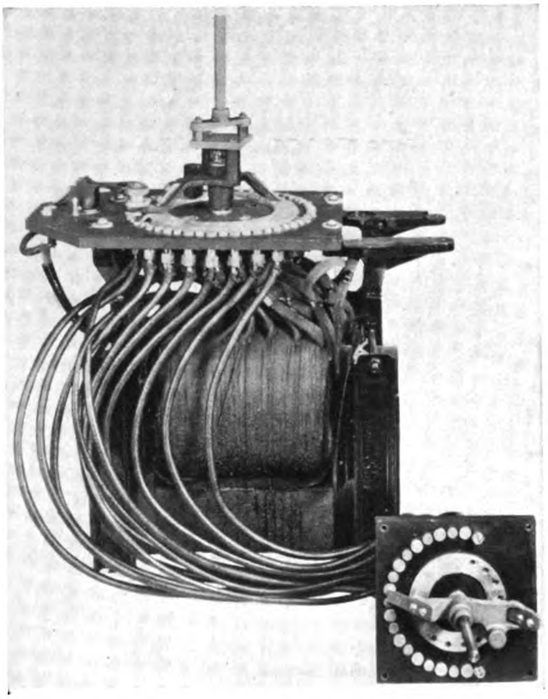

FIG. 19. Typical autotransformer as used in x-ray control circuit showing voltage control and compensator.

Electron Theory and the X-Ray Tube

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THERE IS a large body of observable phenomena in physics which can be explained by assuming the existence of a small electrically-charged particle which has been named the *electron*. This is true of many of the facts pertaining to x-ray tube operation which are more readily understood with a background of information relative to electron properties and behavior. As a matter of fact, the fundamental process of x-ray generation can be said to occur whenever high velocity electrons strike a target; that is, x-rays are generated whenever electrons having a high velocity are suddenly stopped or slowed up by interaction with atoms of other materials in their path. In this process most of the kinetic energy of the electrons is transformed into heat, and only a fraction of one per cent is converted into x-ray energy.

The device in which these phenomena are allowed to occur is called an *x-ray tube*. The elements essential for the operation of an x-ray tube are:

1. A source of electrons.
2. A high voltage with which to accelerate the electrons to high velocity.
3. A vacuum in which the electrons can accelerate without interference from atoms of gas.
4. A target against which the electrons impinge and which then becomes the source of x-rays.

These elements will be described in more detail as this section is expanded.

In the hot cathode x-ray tube developed by Dr. W. D. Coolidge, the type used almost entirely at present, the electron source is a small coil of tungsten wire which is heated to incandescence by the passage of an electric current through it. Figure 20 shows a diagrammatic section of such a tube. The electrons are ejected from the heated wire, the degree of emission being a function of the temperature of the wire and the total area of its surface. Electrons obtained in this manner are distinguished as thermo-electrons, and they have the same characteristics as those obtained by bombardment of gas atoms, ejection from photo-sensitive chemicals, mechanical friction, or any other process by which electrons may be dislodged from an atom or separated from the material in which they exist as free electrons. They carry a unit negative electrical charge equal to 4.77×10^{-10} electrostatic unit, the mass at rest is 9.09×10^{-28} grams, the mean diameter is 2.5×10^{-10} centimeters.

The operating principles of the x-ray tube are best illustrated by further development of the mechanism of electron behavior in a vacuum under the influence of an electric field.

Figure 21 shows a coiled filament with its ends connected to a source of electric potential E_f by which means an electric current I_f is made to pass

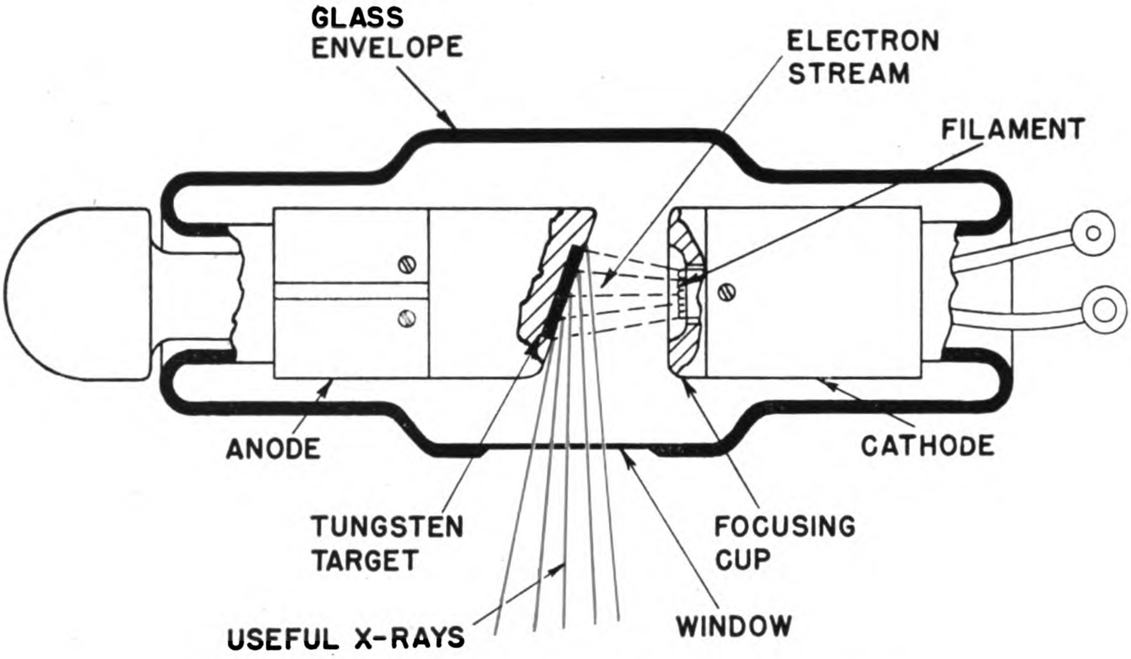


FIG. 20. Diagram of hot cathode tube showing anode and cathode structure.

through the wire. The current passing through the wire raises its temperature to a point where electrons are emitted from the material of which the filament is made. However, if a high temperature is obtained with the filament operating in air, oxidation and rapid deterioration of the filament will take place. It must be enclosed in a space either evacuated or filled with an inert gas which will not affect the filament at high temperature. In the x-ray tube, for reasons which will be discussed later, the filament is operated in a high vacuum of the order of 0.00001 millimeter of mercury. Figure 22 represents the filament in an evacuated glass tube, the lead-in wires brought through the glass by means of a suitable combination of materials to form a vacuum-tight seal. If the space within the bulb is well exhausted, if the absorbed occluded gases on the glass walls and the filament are removed by extended heating processes during the pumping, and if all materials are pure and clean, thermo-electrons will be emitted from the heated filament at a rate fixed by the temperature of the filament wire and its surface area. Control of filament temperature is accomplished by varying the intensity of electric current flowing through the wire. In the diagram this is indicated by an ammeter A and controlled by varying the resistance of the filament circuit through the rheostat R. The heated filament emits electrons, though with small velocity of ejection, from the wire surface. A cloud of particles, each possessing a unit negative electrical charge, is thus formed and equilibrium is established by the electrostatic field produced.

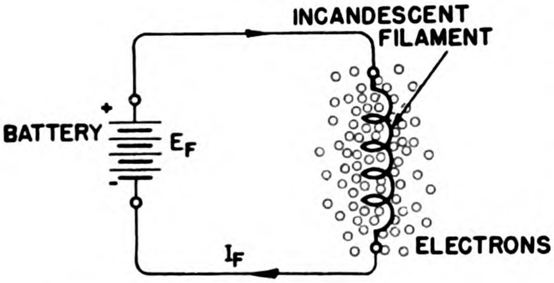


FIG. 21. Method of obtaining electrons by passing an electric current through a wire.

The symbolic representation of a filament heating circuit as shown in Figure 22 will be extended and modified later to a more practical arrangement which will, however, contain the same essentials:

1. A source of filament potential.
2. A tungsten filament in an evacuated glass tube.

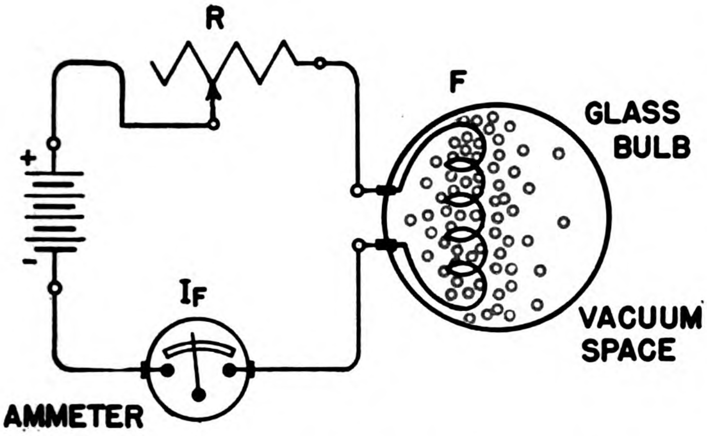


Fig. 22. Elementary filament heating circuit and electron source in evacuated glass bulb.

3. A rheostat for controlling the filament current.
4. An indicating meter for the filament current (ammeter).

Assume now that a collector plate is introduced into the tube and is so connected that its potential is positive with respect to the filament. The negatively charged electrons will be accelerated in the direction of the plate and will constitute an electric current flowing across the vacuum space. Figure 23 illustrates this effect, the plate potential E_p represented by a battery with its positive terminals connected to the plate, and its negative terminal connected to one side of the filament. The plate is termed the anode and the filament is the cathode. If the plate potential is negative with respect to the filament, no current will flow across the vacuum space because of the repulsion of the negative electrons by the negatively charged anode. The electrons passing from the filament to the plate constitute a thermionic current through the vacuum which, because it is a movement of negative charges, is opposite in direction to the conventional current flow from positive potential to negative. This is because the direction of current flow from plus to minus was established before the electron theory was developed. The current through the tube is registered on the milliammeter which may be connected at any point in the anode circuit as, for instance, in the position shown by the meter illustrated by dotted lines.

Electron Emission

With the passage of an electric current through the filament wire, the kinetic energy of the atoms and free electrons, of which the wire is composed, is increased to the extent that some of the elec-

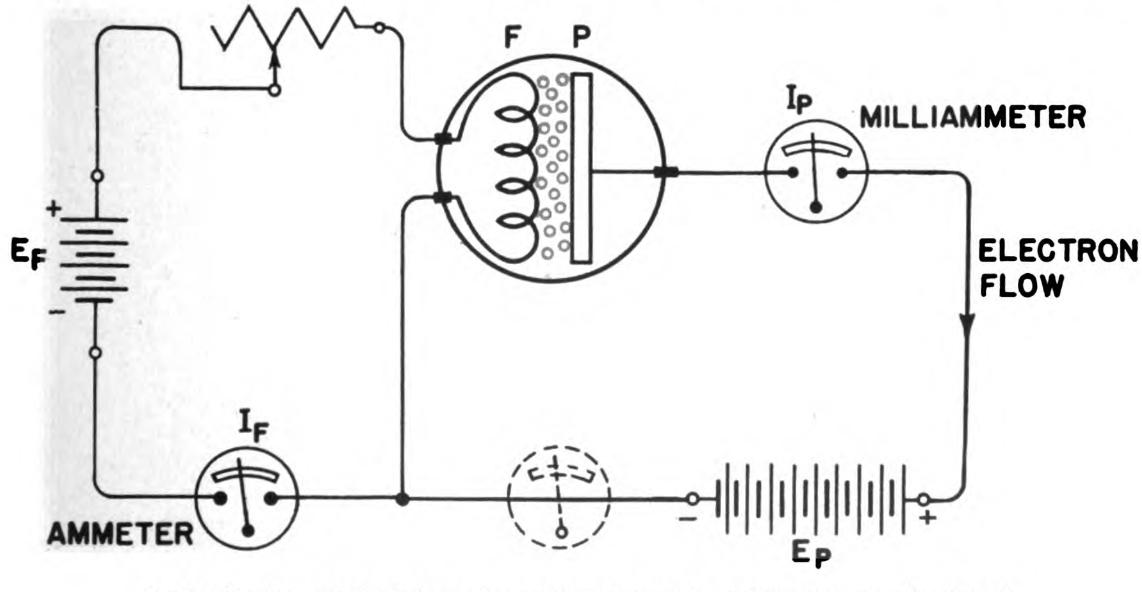


Fig. 23. Fundamental circuit for an electron current through a vacuum tube. The direction of electron flow is opposite that of conventional current flow.

trons will be ejected from the filament surface into the surrounding space. Figure 24 is a curve showing the relation of filament current to emission current for a tungsten wire 0.0085 inch in diameter, a commonly used size. It is seen that small changes in filament current produce large changes in emission.

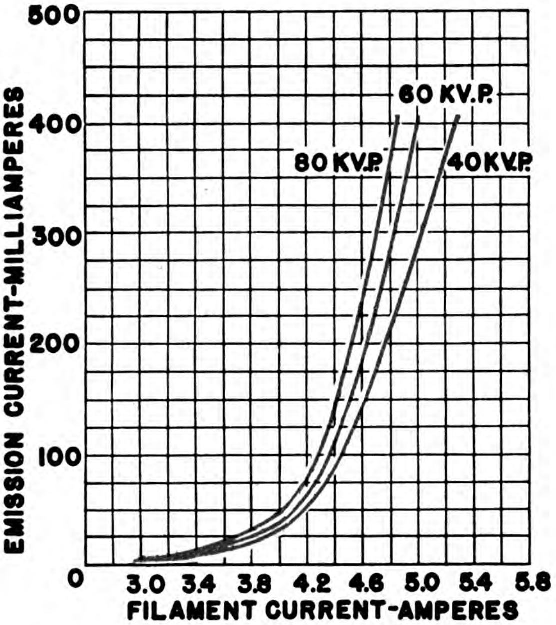


FIG. 24. Emission characteristics of an x-ray tube showing the relation of filament current to emission current.

If the anode potential is sufficiently high to draw all the emitted electrons across the interelectrode space, the relation between thermionic current and filament temperature is given by Dushman's modification of the Richardson equation:

$$I = AT^2e - \frac{b}{T}$$

in which A and b = constants of the filament material which for tungsten are:
A = 60.2
b = 52,400
T = absolute temperature of the filament
e = base of the natural system of logarithms, 2.718
I = thermionic current for each square centimeter of filament surface

From this expression it is seen that the current is limited only by the temperature of the filament and its surface area if all available electrons are utilized in the thermionic current. This condition is approximately met in the x-ray tube, where the anode potential may range from 30,000 volts to 1,500,000 volts, or more.

If the voltage is not sufficiently high, there will be a limitation of current due to the formation of an electron cloud in the vicinity of the filament. The electrical charge of this electron cloud is referred to as *space charge,* which inhibits any increase in current. Elevation in temperature then does not produce any effect on the total number of electrons reaching the anode. Increasing the anode potential, however, will result in further increase in tube current. The relationship expressing the space charge effect is given by the Child-Langmuir law:

$$I_s = kV^{3/2}$$

in which I_s = space charge current
V = potential difference
k = constant depending on the shape of the electrodes, their area, and their distance apart.

This equation shows that for a given temperature of the filament the thermionic current increases with the anode voltage until the saturation current, as obtained from the Richardson equation, is reached.

The tube current is dependent upon the total number of electrons per second passing from cathode to anode. It is of interest to compute this number.

The electronic charge ε is 4.77×10^{-10} electrostatic unit. One ampere-second equals one Coulomb equals 3×10^9 electrostatic unit. The number of electrons per milliampere-second is:

$$1 \text{ mas} = \frac{3 \times 10^9}{10^3} \times \frac{1}{4.77} \times 10^{10} = 6.28 \times 10^{15}$$

electrons, or 6,270,000,000,000,000 electrons.

Electron Acceleration

If the anode voltage is greater than $V = \left(\frac{i}{C}\right)^{3/2}$, the space charge is no longer a limitation and the emission values are limited by temperature alone. The repulsive force between electrons in the space between the anode and cathode is assumed then to be overcome by the field intensity due to the cathode-anode potential difference. All of the electrons emitted from the filament are then accelerated toward the anode under the attractive force of the positive potential on the latter. The term "acceleration" arises from the familiar mechanical concept of a particle, the electron, of mass m and charge e subjected to an electric force E in the interelectrode space. Under these conditions, the particle leaving the filament will be acted upon by force to produce a velocity v at the moment of impact.

The kinetic energy of a particle moving with velocity v is

$$E = \tfrac{1}{2}mv^2$$

The forces acting on a single electron of charge e can be considered. The energy gained by the electron in moving through a field of potential V is

$$E = Ve$$

in which $V = \frac{\text{volts}}{300}$ electrostatic units

$e = 4.77\ 10^{-10}$ electrostatic units

Since the work done upon the electron must appear as kinetic energy,

$$Ve = \tfrac{1}{2}mv^2$$

$$v^2 = \frac{2Ve}{m} = \frac{2e}{m} \times \frac{\text{volts}}{300}$$

$$v = \sqrt{\frac{2 \times 4.77 \times 10^{-10}}{9.09 \times 10^{-28} \times 300} \times \text{volts}}$$

$$5.94 \times 10^7 \sqrt{\text{volts}} \text{ (cm/sec)}$$

$$v = 370\sqrt{\text{volts}} \text{ (miles/sec)}$$

From this expression it is seen that the velocity increases as the square root of the potential difference existing across the tube. The following table, Figure 25, shows electron velocities for tube voltages of interest in x-ray applications.

Potential (Volts)	*Velocity (Miles/Sec)*
1,000	11,700
10,000	36,500
20,000	50,800
50,000	77,200
100,000	102,000
200,000	130,000
400,000	155,000
1,000,000	175,000

FIG. 25. Table showing effect of accelerating potential on electron velocity.

In calculating these values, correction has been made for the increase in mass of the electron as its velocity increases.

In considering the acceleration of electrons by an electrostatic field, it is important to recognize that the presence of gas atoms in the inter-electrode space seriously interferes with the process. Fast-moving electrons have a property of ionizing gas atoms by collision, producing positive ions which, being electrically charged particles, move toward the cathode and constitute a reverse current. In this way the gas becomes conducting and the tube is no longer a pure electron discharge device. In the presence of gas atoms, the electron is able to move only a short distance before collision takes place so that it does not have an opportunity to acquire a high velocity. Since its kinetic energy increases with the square of the velocity, it is evidently important to move as many gas atoms as possible from the inside of the tube, thus increasing the mean free pass between collision to a maximum.

The bombardment of the anode by particles moving at velocities of the order shown in the preceding table produces two effects:

1. The generation of heat at the surface of impact.
2. The generation of invisible radiant energy in the form of electromagnetic waves pro-

ceeding from the surface of impact and slightly below it.

It is the latter which is the useful product of the energy conversion, the x-ray beam.

For a number of years after Röntgen's discovery of x-rays, their nature was not clearly understood. It was finally established that they were similar to visible light waves except for the important difference of having a much shorter wavelength. Figure 26 shows the electromagnetic spectrum of radiations from cosmic rays to long electric waves, the x-rays being associated with gamma rays at their short wavelength limit and ultraviolet at the long wavelength end.

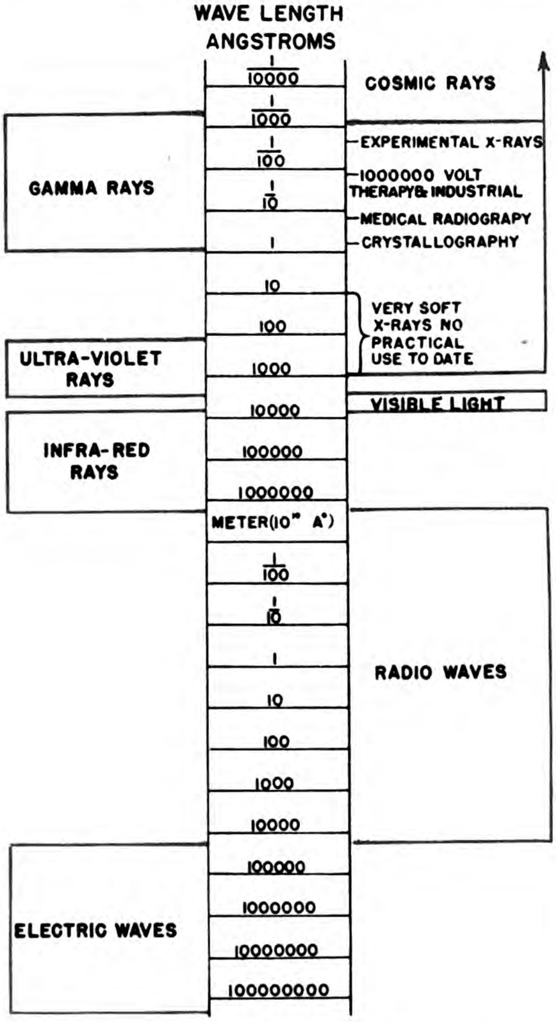


FIG. 26. Table showing electromagnetic radiation spectrum.

The characteristics will be discussed at some length in a following section. At this point a fundamental relationship between the potential applied across the tube and the wavelength of the radiant energy may be established.

The minimum wavelength of the spectrum produced by the bombardment is inversely proportional to the tube voltage. The equation expressing the relation is:

$$\frac{V_e}{300} = h\frac{c}{\lambda_{min}}$$

in which V = tube potential (volts)
e = electronic charge 4.77×10^{-10} electrostatic unit
c = velocity of light 3×10^{-10} cm/sec
h = Planck's constant 6.556×10^{-27} erg sec
λ_{min} = short wavelength limit of radiation

Solving for λ_{min}

$$\lambda_{min} = \frac{hc}{\frac{V}{300}e}$$

Substituting the constants, and expressing the wavelength in Angstrom units (10^{-8} cm)

$$\lambda_{min} = \frac{12{,}354}{\text{Volts}}$$

Of the total energy in the cathode stream, only a very small portion is effective in the production of x-rays, the remainder being dissipated in the form of heat in the anode. An empirical formula for the efficiency of x-ray generation is:

Efficiency = $ZV \times 10^{-9}$
in which Z = atomic number of target
V = tube voltage

Assuming a tube operating at 50,000 volts (d.c.) and a current of 20 milliamperes, the electrical input, exclusive of filament heating, is

1000 watts. If the anode material is tungsten, atomic number 74, the efficiency of x-ray production is:

$$\text{Efficiency} = 74 \times 50{,}000 \times 10^{-9}$$
$$= .0037 \quad = 0.37 \text{ per cent}$$

The energy lost as heat in the anode is then

$$1000 \times 0.9963 = 996.3 \text{ watts}$$
$$H = .24\ EIt \text{ calories}$$

If the electron beam is 10 mm square, the dissipation is 99.63 watts/sq mm, a quantity which is equal to about 24 calories per second. Neglecting heat radiation and conduction from the area of electron impact, and assuming a tungsten target of specific heat 0.032, the temperature rise at the focal spot is of the order of 750° C. per second.

The X-Ray Tube

In the design of a vacuum tube specifically for x-ray production, the following requirements may be predicted from the foregoing analysis.

1. The source of electrons will be a material capable of stable electron emission at elevated temperature and possessing the necessary properties of mechanical strength, long life, and ease of degassing. Ductile tungsten as a source of electrons in the electron discharge tube was first developed by Dr. W. D. Coolidge in 1912, and is still universally used.
2. The anode or, more specifically, that portion of the anode subjected to electron bombardment, will be a material of high atomic number, since the efficiency of x-ray production increases with the atomic number of the target material. Tungsten, with an atomic number of 74, is generally used.
3. The target, as described above, must be capable of withstanding high temperatures since practically the entire electrical input to the tube is converted into heat in the area of electron bombardment. Because of its high melting point, tungsten is a desirable material to use for this portion of the anode.
4. The tube will be operated with a high potential difference between the anode and cathode in order to impart high velocity to the electrons and so to produce x-rays of a wavelength suited to the particular application of the tube. This high potential influences the design of the x-ray tube and necessitates consideration of the over-all length of the tube, the thickness of the glass walls, the degree of vacuum to which the tube is exhausted, and the electrode design and configuration to produce a uniform electrostatic field.
5. In order that the current through the tube be a pure electron discharge, all gases must be pumped out of the space within the bulb to as complete a degree as possible, the anode and cathode must be thoroughly outgassed by special exhaust procedures, and the glass itself must be freed from occluded gases by subjection to elevated temperatures during the pumping operations. The final pressure will be 0.00001 millimeters of mercury or less, thus safely reducing the gas atoms capable of being ionized by electrons to a number well below the safe limit for the potentials employed in x-ray practice.
6. Because high velocity electrons striking the target are reflected and collect on the inside surface of the glass walls in the vicinity of the anode, attention must be paid to the negative potential built up in this manner. The shape and size of the anode and cathode, together with the configuration of the glass bulb itself, must be such that freedom from puncture and erratic operation are assured.

Figure 27 is an illustration of a typical x-ray tube utilized in diagnostic applications of which Figure 20 is a sectional drawing.

The electron source is a filament of fine tungsten wire .0085 inch in diameter, coiled in the shape of a helix and set into a metal cup in which is milled a rectangular slot. The size and shape of the electron beam are controlled by:

1. The filament length.
2. The coil diameter.
3. The width of the focusing slot.
4. The length of the focusing slot.
5. The depth of the filament in the cup.
6. The electrode configuration.

The electron beam cross-sectional area is of prime importance in determining sharpness of radiographic detail and the permissible energy output from the tube. Figure 28 shows the effect

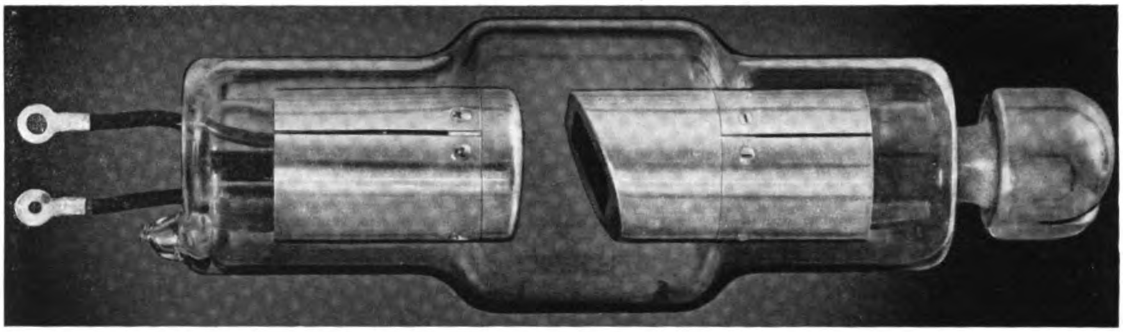


FIG. 27. Typical x-ray tube used for radiographic application designed for operation up to 100 kilovolts peak.

of focal spot size on detail sharpness in a radiographic projection. Due to the fact that x-rays are emitted from the entire surface of the focal area, a series of shadows of a projected point are obtained on the film, which results in a diffusion of detail. If the focal spot is decreased in size, the projected area of the x-ray source is correspondingly decreased and the diffusion of detail is reduced. If the angle of the anode is changed and made more nearly perpendicular to the axis of the tube, the effective projection is decreased but the size of film which can be covered is correspondingly decreased and the variation in effective size from the anode to the cathode end of the tube becomes very great. Figure 29 is a curve showing the relation of focal area to permissible current-carrying capacity for a given voltage and time. The focal spot size, as a factor affecting the tube rating, will be discussed in a subsequent section.

The electron beam is usually of rectangular cross-section with its long dimension about three times its width. For a given electron beam, the angle of the anode face is made such that a square projection results at 90 degrees to the long axis of the tube. In most modern x-ray tubes used for diagnostic application, the anode angle is from 15 degrees to 22 degrees. The area effective in heat dissipation is then about three times as great as the area over which the x-ray source is spread when the latter is observed from the point of view of the film directly below the center of the anode.

The filament and the focusing cup are supported on a metal cylinder which extends over the glass-metal seals through which the filament lead wires are brought into the tube. The entire structure constitutes the cathode element.

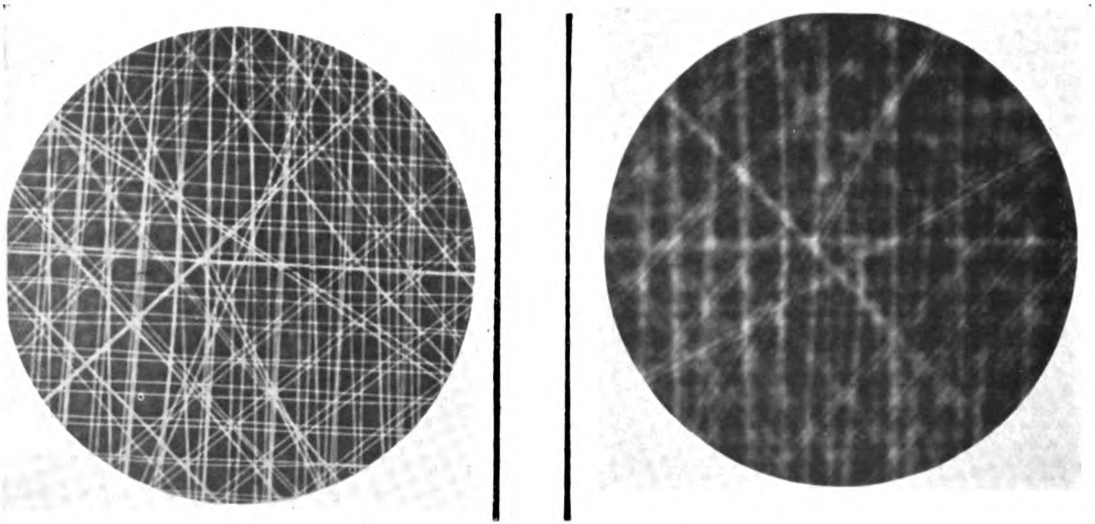


FIG. 28. Effect of focal spot size on sharpness of projected image.

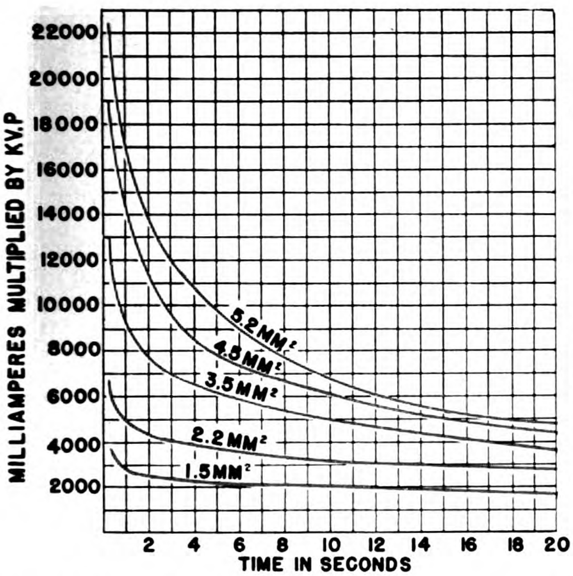


FIG. 29. Comparison of tube ratings for different sizes of focal spot, full-wave rectified circuit.

The source of x-rays is the target, generally a rectangular ductile tungsten block approximately 0.10 inch in thickness around which is vacuum cast a copper anode which serves to remove the heat from the tungsten surface by conduction. Tungsten, because of its low vapor pressure and high melting point, can be operated at a temperature as high as 2700° C. The copper backing serves to conduct the heat from the tungsten target to the outside of the tube, and is generally in the shape of a massive copper block many times larger than the focal area itself. With such an arrangement the power input to the tube may be as much as 250 watts per square millimeter of focal area.

Figure 30 in a photograph of an x-ray tube oil-immersed in a shockproof x-ray protective casing. The sequence of heat dissipation is as follows: from the focal area to the copper anode, through the anode to the radiator, from the radiator by conduction and convection through the oil to the casing, and by radiation and convection to the surrounding air.

X-Ray Tube Rating

The principal factors limiting the energy rating of the x-ray tube are *first,* the limitation due to temperature at the focal area, an excess of which may cause melting of the target; *second,* the limitation due to the thermal capacity of the tube and casing together with the effectiveness of the latter in dissipating heat to the surrounding air; and *third,* the voltage limitation which determines the maximum kilovolts peak rating and is affected by such factors as: the length of the tube, the spacing of the elements, the shape of the electrode and the envelope, the type of glass

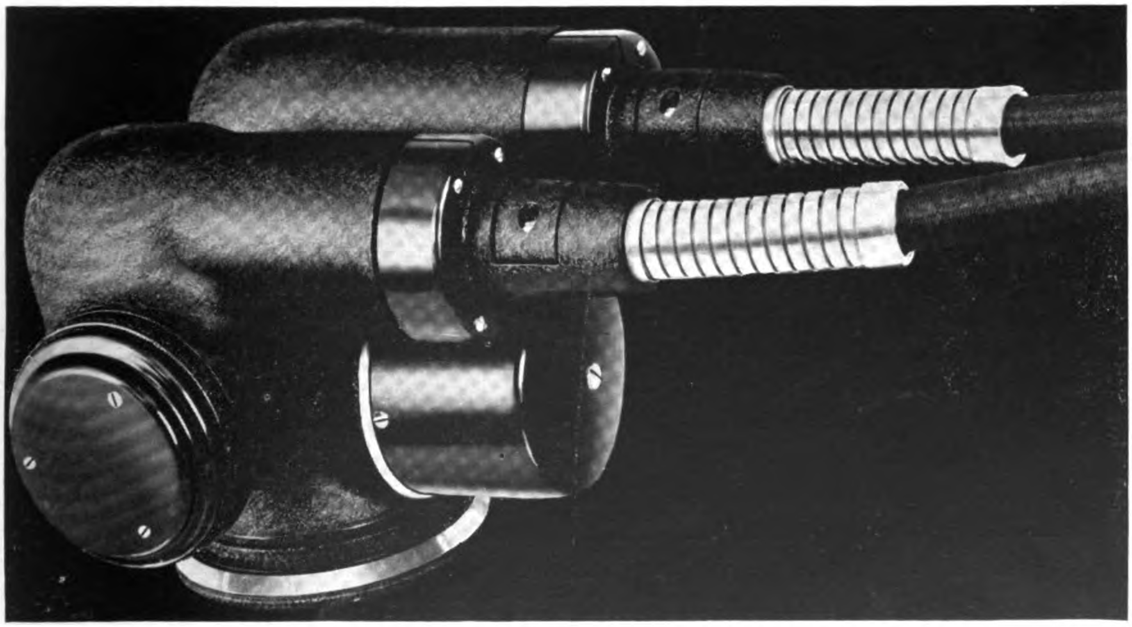


FIG. 30. X-ray tube oil-immersed in a shockproof x-ray protective casing.

used, and its thickness. For short times of exposure, that is, 1 second or less, the tube rating is based mainly on the focal area melting energy; for longer times, the entire anode becomes effective as a cooling medium and energy transferred to it by conduction may raise its temperature to a limiting value based on the possibility of the liberation of gas from the anode or on the melting point of the copper or the soldered joints within the tube.

Figure 31 is a table showing the comparative safe ratings for tubes of different focal areas but of identical dimensions, mass, thermal capacity, and heat emissivity. The values given are conservative recommended current limits for tube voltages of 70 kilovolts peak. It is seen that the rating depends to a great extent on the focal area for the 1/10 second column, but that the difference is much less for a time of 20 seconds.

Focal Spot Size	*Current Rating (MA.) at 70 KV.P., Full Wave*		
	1/10 Sec.	*5 Sec.*	*20 Sec.*
1.5 mm.^{2}	50 MA.	30 MA.	25 MA.
2.0 mm.^{2}	80 MA.	45 MA.	35 MA.
2.2 mm.^{2}	95 MA.	55 MA.	40 MA.
3.5 mm.^{2}	190 MA.	85 MA.	55 MA.
4.5 mm.^{2}	270 MA.	110 MA.	65 MA.
5.2 mm.^{2}	330 MA.	120 MA.	70 MA.

FIG. 31. Table showing comparative current ratings for various sizes of focal spots at 70 kilovolts peak.

The rating of an x-ray tube is a complicated function of a large number of variables which can best be determined by empirical tests and accumulated design data from such experiments. Limits of safe operation are then expressed in the form of tube rating charts for each type of tube and for each focal area manufactured in that type. One of these is shown in Figure 32 for a focal spot 4.5 millimeters by 4.5 millimeters, measured in projection at right angles to the tube axis in accordance with the conventional expression of focal spot sizes. The three factors given by the curves are:

1. Time of exposure.
2. Tube voltage (kilovolts peak).
3. Tube current (milliamperes).

With any two of these known, the third is found at the point of their intersection. For example, the safe current at 70 kilovolts peak and 1/10 second is 270 milliamperes; the tube voltage limit at 200 milliamperes and 1/10 second is 94 kilovolts peak; the maximum time of exposure at 100 milliamperes and 100 kilovolts peak is 1¾ seconds. Note that the tube current or tube voltage that can be applied to the tube for 1/10 second is far less than that which is permissible for 1 second. In other words, the ratings are not linear functions of time and cannot be casually interpreted.

So far nothing has been said of the influence of the type of circuit on the rating of the tube.

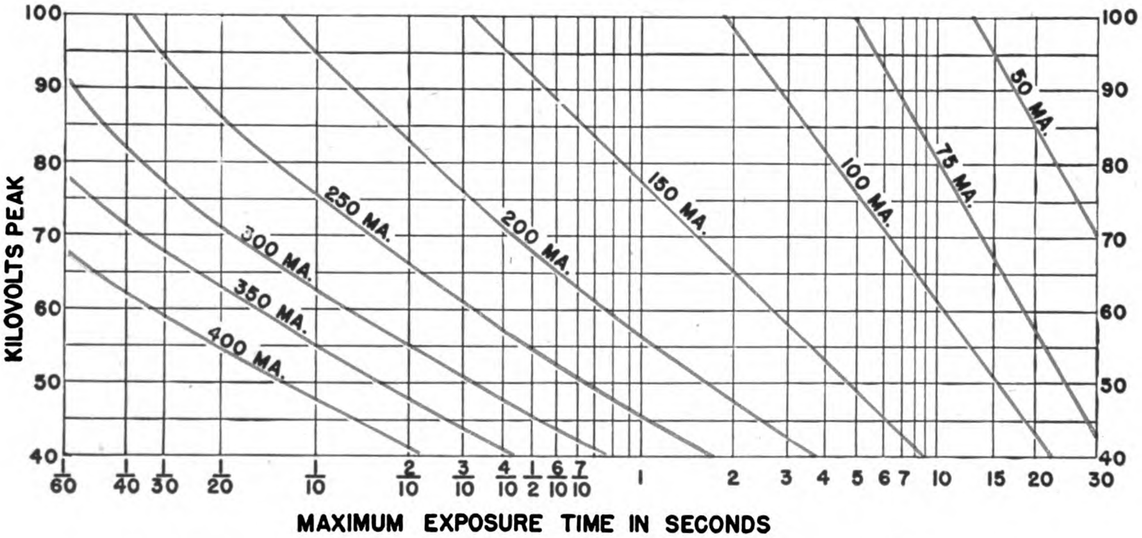


FIG. 32. Energy rating chart for a 4.5 millimeter focal spot on a full-wave rectified generator.

In a later section the characteristics of different types of x-ray generators will be discussed more completely. The power supplied to the x-ray tube is generally single-phase self-rectified, single-phase full-wave rectified, or three-phase. In some therapy generators, single-phase half-wave rectifiers are used, but none of these are made for radiographic generators at the present time. Figure 33 shows the comparative energy rating for a 4.5 millimeter focal spot on the different types of circuits. It is seen that for the single phase supply the tube rating on a full-wave rectified generator is higher than that for a self-rectified circuit, while the three-phase rating is between the two for most time values.

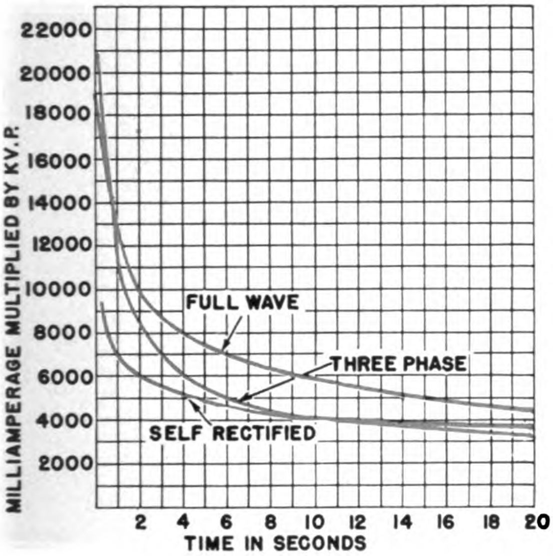


FIG. 33. Comparative maximum rating for a 4.5 millimeter focal spot on various types of x-ray generators.

Cooling Curves

The rating chart only partially specifies the safe operating characteristics of an x-ray tube since it indicates the limitation for a single exposure but gives no information as to the rapidity with which the exposures may be made. The gradual rise of anode temperature as the tube is used will cease only when equilibrium is reached between the rate at which heat is generated by the electron bombardment of the anode and the rate at which it is removed from the tube. Safe limits must be specified for the total energy input, expressed preferably in electrical units, and the time of cooling necessary after the limit is reached. Such data are given in cooling curves as shown in Figure 34. For convenience in use, an arbitrary energy unit is used; namely, the product of kilovolts peak times milliamperes times seconds. This is related to the watt-second, and can be converted into calories if the effective value of the tube voltage is known. For a full-wave rectified circuit, assuming a sine wave form, the heat input in calories is

$$\begin{aligned} H &= 0.24 \text{ watt-second} \\ &= 0.24\ (.707 \text{ kvp}) \frac{(.707 \text{ ma})}{.636} \text{ seconds} \\ &= 0.19 \text{ kvp ma seconds (calories)} \end{aligned}$$

It is because kilovolts peak, milliamperes, and time are specified factors in x-ray technic that it has been found advantageous to utilize them rather than the generally employed heat unit, the calorie.

From the curves it is seen that the maximum permissible heat input is 250,000 kilovolts peak-milliampere-seconds units, and that after such a value has been applied, an interval of 30 minutes must elapse before the same quantity can again be utilized, or after an interval of five minutes, 100,000 heat units can again be put into the tube. The rate of cooling depends on the initial temperature, being about 25,000 kilovolts peak-milliamperes-seconds per minute, starting from 250,000 and 4000 heat units per minute starting from 50,000.

In using the chart, the total heat input for a series of exposures is computed and if the maximum is reached during the procedure, a time interval must elapse based on the energy contained in the next series of exposures and the time for loss of this amount from the tube. For example, if after 230,000 heat units have been absorbed, it is desired to apply an additional 70,000. If no cooling period is allowed, the heat input will be 300,000 heat units, a value in excess of the tube unit. It is necessary to permit the tube to cool 50,000 heat units from 230,000, which requires, from Figure 34, 2½ minutes.

The rating of a tube for intermittent duty cycles of long duration, as in fluoroscopy or therapy applications, is simply specified as in terms of the number of minutes of operation allowable in a given time interval at various power inputs. For example, the rating of the DX tube unit is 85 kilovolts peak and 5 milliamperes, or

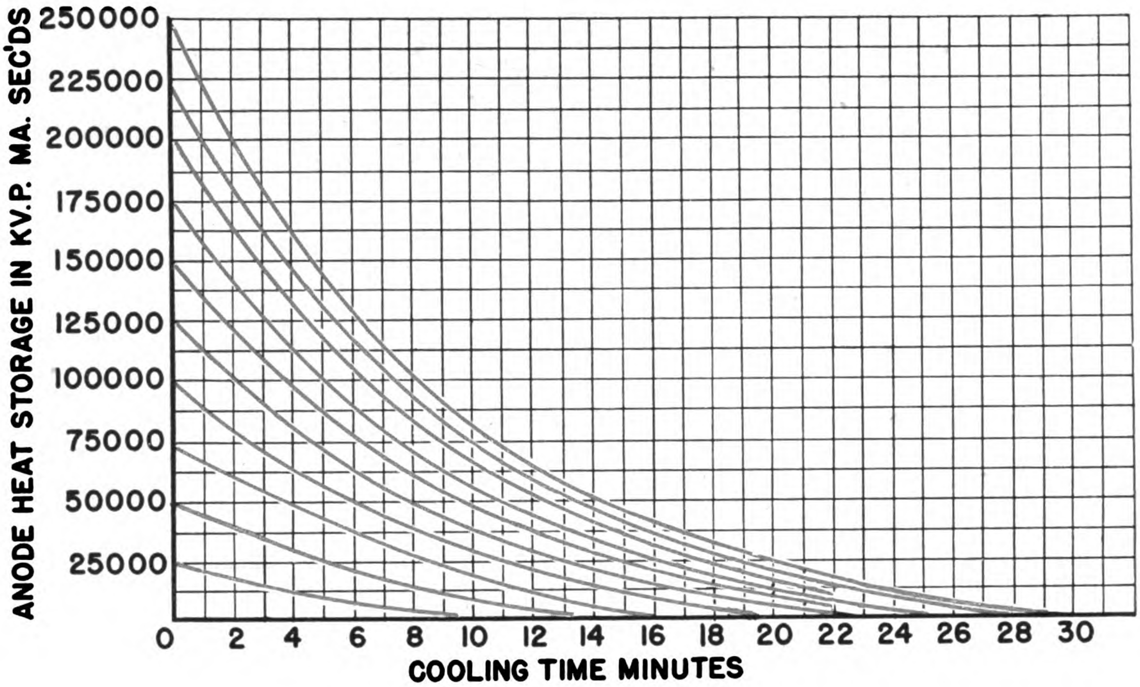


FIG. 34. Cooling curve for a shockproof radiographic tube unit (DX2-4.5).

100 kilovolts peak and 4 milliamperes for 10 minutes of each 20-minute period over a maximum period of 3 hours. At 85 kilovolts peak and 3 milliamperes, the allowable time is 15 minutes of each 30-minute period for a maximum of 4 hours. If a motor-operated cooling fan is mounted on the casing, the rating is increased to continuous duty at 85 kilovolts peak and 5 milliamperes or 100 kilovolts peak at 4 milliamperes.

Some tubes designed for continuous operation are provided with hollow anodes through which oil is circulated as a cooling medium. Such tubes are extensively used in deep therapy and industrial radiography applications.

Filament Emission Characteristics

Thus far two forms of expression of the capacity of an x-ray tube have been discussed: the rating chart which gives the focal area limitation for single exposure, and the cooling curves which describe the total tube heat capacity and rate of heat loss for a series of exposures. There is a third set of characteristics which is quite important in the operation of the tube, particularly for the high-milliampere short-time exposures used in roentgenographic procedures. These are the curves showing the relation of filament current to emission or tube current expressed in such form that it is possible to pre-set the filament ammeter for any desired milliampere value.

For the higher values of allowable tube current, the permissible exposure times are too short for a preliminary setting of the filament current by observation of the milliammeter during a test exposure. Even for those values where the rating permits testing, this may account for an appreciable portion of the life of a tube and should for this reason be avoided.

Filament Increment Curves

In order to obtain satisfactorily accurate filament current settings, independent of the inertia of the milliammeter and without the necessity for testing the tube preliminary to an exposure, charts known as filament increment curves are employed. With the filament characteristics of a tube given as determined for a given type by experiment, it is possible to establish, without testing, the filament current for any desired tube current value and kilovoltage. Figure 35 shows a set of three curves obtained for a 4.5 millimeter focal spot in a shockproof oil-immersed tube. With these curves it is possible to read the filament current for any desired value of kilovolts

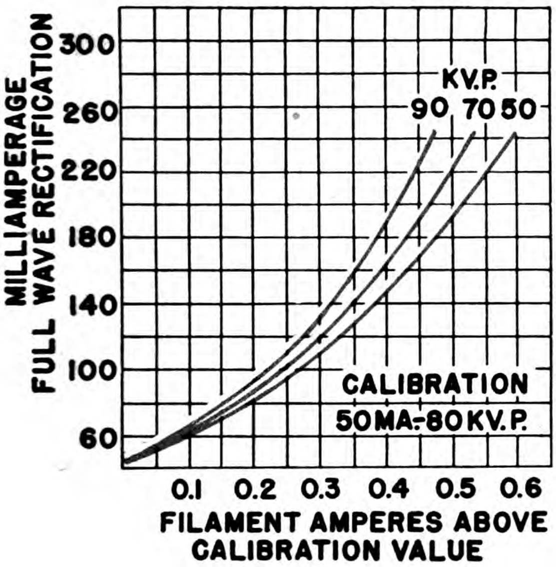


FIG. 35. Emission characteristics for a 4.5 millimeter focal spot on a full-wave rectified generator.

peak and milliamperes, and to set the ammeter accordingly. The curves, however, apply only to the tube for which the data has been collected, and for its change as the filament characteristics change during the life of the tube.

In actual practice, this procedure is modified somewhat so that all tubes of a given type can be represented by a family of curves which do not change with filament life and any particular tube is fitted to this data by a preliminary checking operation well below the energy limitation of the tube. These curves are obtained from data on a large number of tubes of a given type (same electrode dimensions, same spacing, same bulb diameter, and same configurations). Any particular tube is then fitted to the curve by the determination of a single emission value, low enough so that the tube may be safely operated for a time sufficient to allow the milliammeter to come to rest, this being two seconds or longer. The test value is 50 milliamperes on a full-wave circuit, and 25 milliamperes on a half-wave circuit, the tube voltage being 70 or 80 kilovolts peak. The filament current for 50 milliamperes (full-wave) is the baseline from which, with the filament increment curve, all filament settings for the higher milliampere and kilovolts peak values can be quickly determined. Filament evaporation does not affect the accuracy of the method because the baseline setting may be rechecked at frequent intervals during the life of the tube and corrections made to all current settings by the amount of the baseline change.

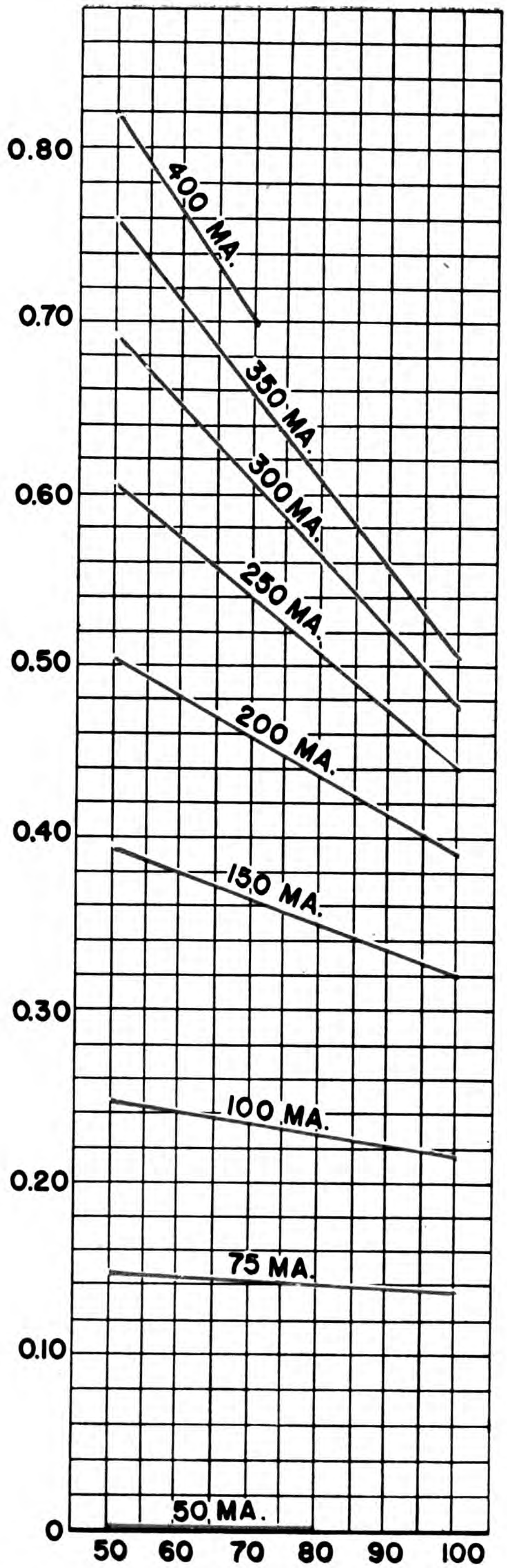
As an illustration, assume that the base setting for a tube is 4.20 amperes. The filament setting for 200 milliamperes and 80 kilovolts peak is to be found. Referring to Figure 36, the increment for 200 milliamperes and 80 kilovolts peak is 0.44 amperes, which, added to 4.20, gives 4.64 as the 200-milliampere setting. As long as the base value continues at 4.20, this will be correct and any changes over the tube life period can be determined by checking the 50-milliampere setting at regular intervals, preferably every 100 exposures. The accuracy of the method depends on the degree of variation permitted between the type curves and each individual tube. This is a problem of production control and is subject to a satisfactory degree of accuracy. The actual milliampere values obtained by this indirect method are in most instances slightly below those values given in the curves. Radiographically, however, the effect of this variation on film density is scarcely perceptible while from the standpoint of tube safety the latitude always is on the conservative side.

It has been found from experience that a simplification of the method may be introduced by determining the filament increments for but one tube voltage, the highest which is likely to be utilized, usually 90 kilovolts peak. This figure is then used regardless of the kilovolts peak employed with the assurance that the tube current will never be greater than the desired value. It will decrease at lower potentials, but due to the compensating effect of transformer regulation, the voltage will be slightly over the anticipated value so that the two effects on film density practically cancel one another.

Effect of Space Charge

The fact that space charge does exist in every hot cathode tube means but little unless the operator understands its effect on the radiograph as well as on the x-ray tube.

As previously explained, the temperature of the tube filament governs the current (milliamperes) through the tube under certain conditions. Further, milliamperage is controlled by varying the tube filament temperature by changing the tube



filament current (amperes). However, the operator must bear in mind the influence of kilovolts peak on milliamperes, even though the tube filament temperature is constant.

The filament increment curves take this into consideration, and a careful study of these curves for a given tube and focal spot size will reveal that unless the proper recognition is given to the effect of space charge, consistent results will be impossible, and, further, the tube may be seriously damaged due to overload.

As the kilovolts peak value is varied for a given filament temperature, the milliampere value in turn is changed. The *higher* the kilovolts peak for a given filament temperature, the *higher* the milliamperes. The *lower* the kilovolts peak for a given filament temperature, the *lower* the milliamperes.

The lower the milliampere value being employed, the less the effect of space charge. The higher the milliampere value, the greater the effect of space charge.

For example, if the tube filament temperature is set for 30 milliamperes, 40 kilovolts peak, an increase in kilovolts peak to 80 would cause only a slight increase in milliamperes. However, if the tube filament temperature is set for 100 milliamperes at 40 kilovolts peak, an increase to 80 kilovolts peak would cause an appreciable increase in milliamperes. As the milliamperes are increased still further, the change becomes more marked. This increase is such that not only will radiographic quality be affected, but serious damage to the tube may result.

Consequently, except when this effect is automatically controlled in the apparatus, the filament settings must be varied to maintain a constant milliamperage over wide changes in kilovolts peak.

Effect of Filament Evaporation

It is well to repeat that all x-ray tube filaments evaporate over a period of time. The rate of evaporation depends mostly upon the temperature of the filament and the length of time it is lighted. Especially does this apply to leaving the

Fig. 36. Filament increment data for a 4.5 millimeter focal spot on a full-wave rectified generator.

filament "ON" for sustained periods of time at the higher temperatures.

The effect of filament evaporation is to increase its temperature for a given ampere value. The result is that the milliamperage through the tube increases, oftentimes without the operator's knowledge, particularly if high milliampere, short-time exposures are being used. As the milliamperage increases, the kilovoltage decreases (depending upon regulation of the circuit), but ordinarily not enough to offset danger to the tube. (See tube rating charts for the effect of milliampere changes versus voltage changes on the tube.)

Thus the recommendation to check the baseline milliampere value every 100 exposures, and make the necessary adjustment of filament current to compensate for filament evaporation.

Milliampere-Second Meter

The milliampere-second meter is a device which measures the product of milliamperes and time. It is designed electrically and mechanically so that the indicator (needle) is very slow moving. This design permits the operator to readily read the excursion of the indicator on the dial, which is calibrated in milliampere-seconds.

This meter should be used only in combination with an impulse timer if dependable results are to be obtained. It should be obvious that the timer must be both accurate as to time and consistent in operation. All timers other than the impulse type vary, particularly in consistency. For example, plus or minus 10 per cent or more for 1/20 to 1/10 second will be reflected in the reading of the milliampere-second meter. As its primary purpose is to establish the milliampere value, it can be seen that if the time factor is unknown, the milliampere-second reading means little or nothing to the operator.

If used as a means of adjusting the filament ammeter for a desired milliampere value, using a timer other than the impulse timer, some degree of accuracy can be established by making exposures of a spinning top (Chapter IV) reading the milliampere-seconds at the same time. Thus, with the time known, the milliamperes can be computed from the milliampere-second value.

As previously stated, proper increment curves make possible the pre-setting of milliamperes without the necessity for testing the tube at harmful values. Procedures necessitating the minimum of tube testing provide for longer tube life.

The Rotating-Anode Tube

The limitation in energy rating of an x-ray tube set by the temperature of the focal area has been offset to a great extent by the development of the rotating-anode tube. If the area of electron bombardment on the target is moved with respect to the electron stream so that for the entire duration of an exposure the surface under impact is constantly changing, then no portion of the anode surface will be subjected to continuous electron bombardment as in the case of the stationary-anode tube. Figure 37 is a diagram of a disc anode which is bombarded by an electron stream of rectangular cross-section in a small area on its periphery. The disc is made to rotate during the period of operation so that the portion of the anode bombarded by electrons is a ring, the outer circumference of which is approximately the same as the outer circumference of the anode itself, and the inner circumference of which is determined by the length of the focal spot. The anode angle and dimensions of the electron stream are so arranged that the projection is a square when measured in the usual way. Figure 38 shows a cross-section of a rotating-anode tube of current design. A solid tungsten disc is cast into a massive black coated copper anode which greatly increases the radiating area and the heat storage capacity of the tube. The copper anode rotates

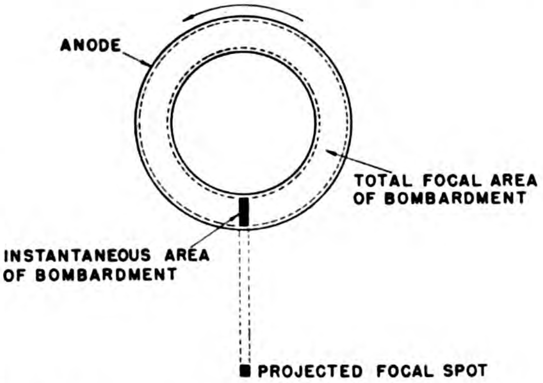

ANODE
TOTAL FOCAL AREA OF BOMBARDMENT
INSTANTANEOUS AREA OF BOMBARDMENT
PROJECTED FOCAL SPOT

FIG. 37. Diagram showing electron impact area and total area of bombardment for a rotating-anode.

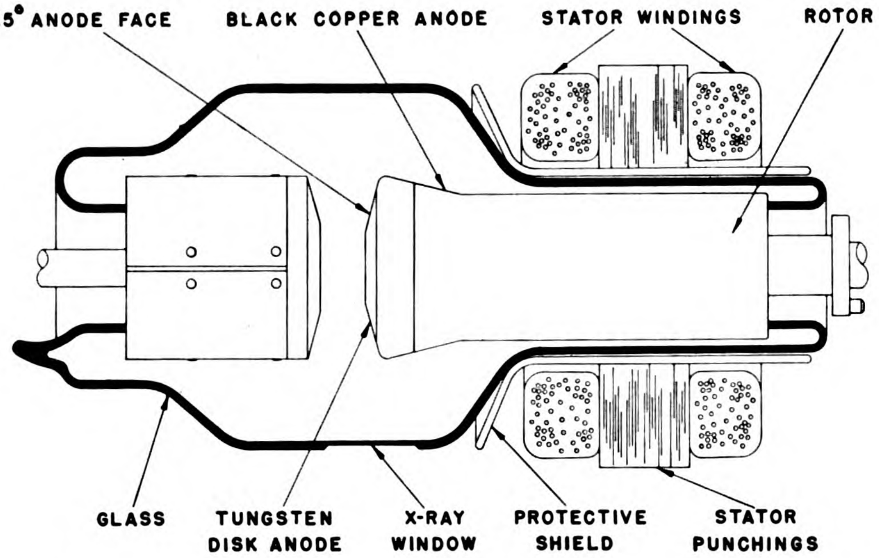


FIG. 38. Cross-section of a rotating-anode tube showing principles of design.

on an axis through the center of the tube with the filament offset with respect to this axis so as to direct the electron stream against the beveled periphery of the tungsten disc.

The focal area is fixed in size and shape, but the region of bombardment on the disc is, for one

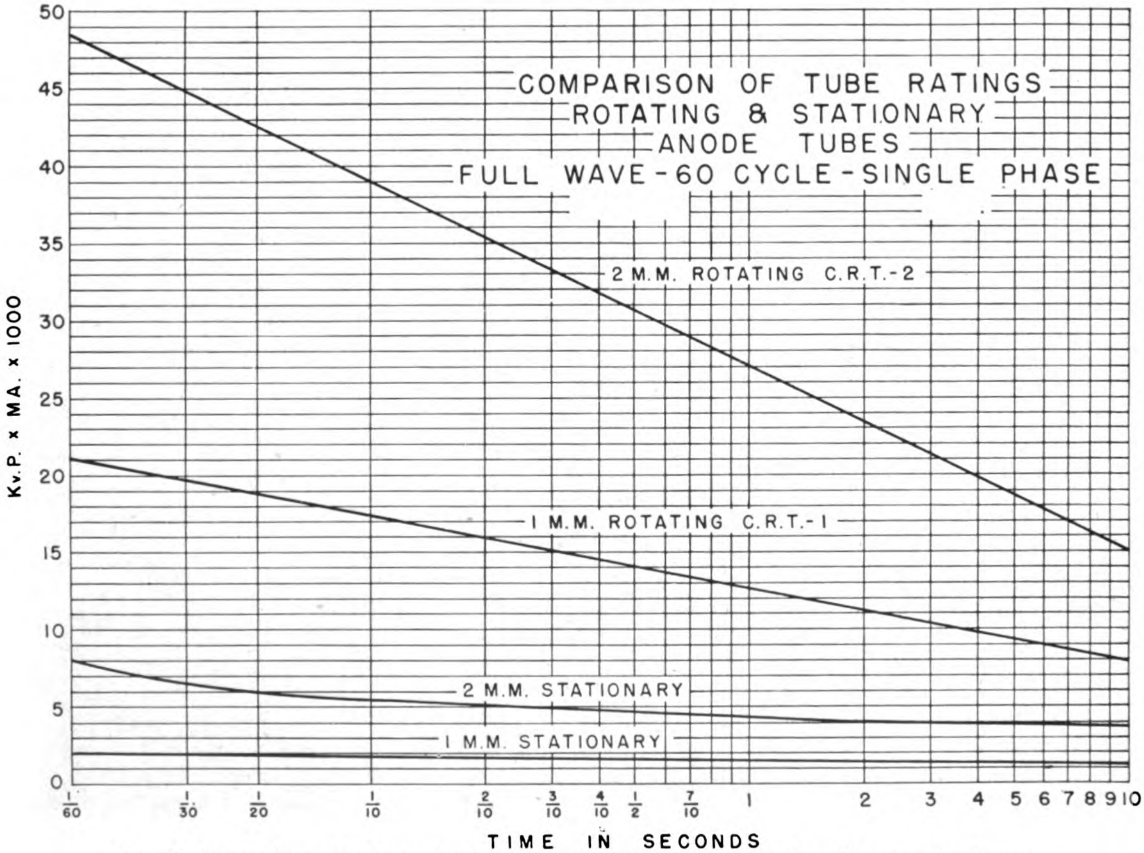


FIG. 39. Comparison of tube rating for rotating- and stationary-anodes with same focal areas.

complete revolution, a ribbon equal in length to the disc circumference and in width to the length of the focal area as shown in Figure 37. With the speed of rotation of 3400 revolutions per minute, it is evident that the disc rotates once in 1/56 second. For a projected focal area 2 millimeters square on a 15-degree target, the actual bombardment takes place over an area 7.5 millimeters wide and 150 millimeters long. In a stationary-anode tube with the same projected focal area, the dimensions of the area of electron bombardment would be 7.5 millimeters by 2 millimeters.

The current-carrying capacity of the rotating-anode tube for a given projected focal area is much greater than that of the stationary-anode tube, while for equivalent ratings the rotating-target tube will have a much smaller focal area than the stationary-anode tube. For a 2-millimeter focal spot, the ratio is 750 per cent at 1/20 second, and 500 per cent at 10 seconds. For a 1-millimeter focal spot, it is 640 per cent at 1/20 second, and 560 per cent at 10 seconds. Figure 39 shows comparative ratings in terms of tube current at a constant kilovolt peak value for rotating and stationary anode tubes used on 60-cycle, full-wave rectified circuits at 85 kilovolts peak. A stationary-anode tube with the same energy rating as the 2-millimeter focal spot of a rotating-anode tube would require a focal spot of approximately 6 millimeters by 6 millimeters. To duplicate the rating of the 1-millimeter focal spot rotating, a focal spot approximately 4 millimeters by 4 millimeters would be required on a stationary-anode tube. By the principle of anode rotation, the advantages of high power, short-time radiographic technics are obtained without the sacrifice in detail sharpness caused by large focal spots ordinarily necessary to handle adequately the increased power.

CHAPTER III

Basic X-Ray Generating Circuits

THEORY OF OPERATION, SELF-RECTIFIED GENERATOR 34
LIMITATIONS OF THE SELF-RECTIFIED CIRCUIT 36
VALVE TUBE (KENOTRON) RECTIFICATION 38
THE FULL-WAVE KENOTRON RECTIFIER 40
THE HALF-WAVE KENOTRON RECTIFIER 42

IN CHAPTER I the fundamental concepts of voltage, current, and resistance were discussed, and the alternating-current transformer in the three forms utilized in x-ray practice was developed; in Chapter II the essential principles of x-ray production with their elaboration in the form of the x-ray tube were discussed. In Chapter III these elements will be combined into x-ray generators of the type generally employed in modern diagnostic practice. The essential elements of the simplest form of such a circuit are illustrated in Figure 40 and consist of:

1. A filament transformer to supply heating current to the filament of the x-ray tube.
2. A rheostat for controlling the filament current.
3. An ammeter for indicating the filament current.
4. A transformer to supply the necessary voltage for electron acceleration (high voltage transformer).
5. An autotransformer for controlling the accelerating voltage.
6. A line voltage compensating control and indicating voltmeter.
7. A milliammeter for indicating tube current.
8. A switch for initiating and terminating the x-ray exposure.
9. A line switch for disconnecting the entire apparatus from its power supply.

It is desirable to analyze the action of the various components of this circuit, since from it a considerable amount of information can be obtained regarding even the most elaborate and complex modifications which are found in present-day generators.

Starting with the filament heating circuit, upper left in Figure 64, the filament is connected directly to the secondary winding of the filament transformer which, from the discussion in the preceding chapter, is recognized as a device for insulating the filament and reducing the power supply potential to approximately 10 volts as required by the tube filament. The filament potential and current are controlled by a variable resistance unit, or rheostat, Figure 41, acting in the primary circuit of this transformer. The total line voltage is divided between that necessary to overcome the resistance of the rheostat and that impressed across the primary winding of the filament transformer. The variable drop across the former fixes the latter, which in turn establishes the filament current. The ammeter in the filament circuit is shown in the primary, a common practice since it is then at low potential and may be mounted on the control stand. Were it placed in the secondary circuit for direct reading, its potential with respect to ground would be that of the cathode of the x-ray tube, which is half the full tube voltage. It would be necessary then to mount the meter with sufficient clearance to insulate it for as much as 50 kilovolts peak from surrounding objects. This was general practice in older x-ray installations in which the open type overhead conductors were utilized for connecting the transformer to the x-ray tube. Now that shockproof apparatus is

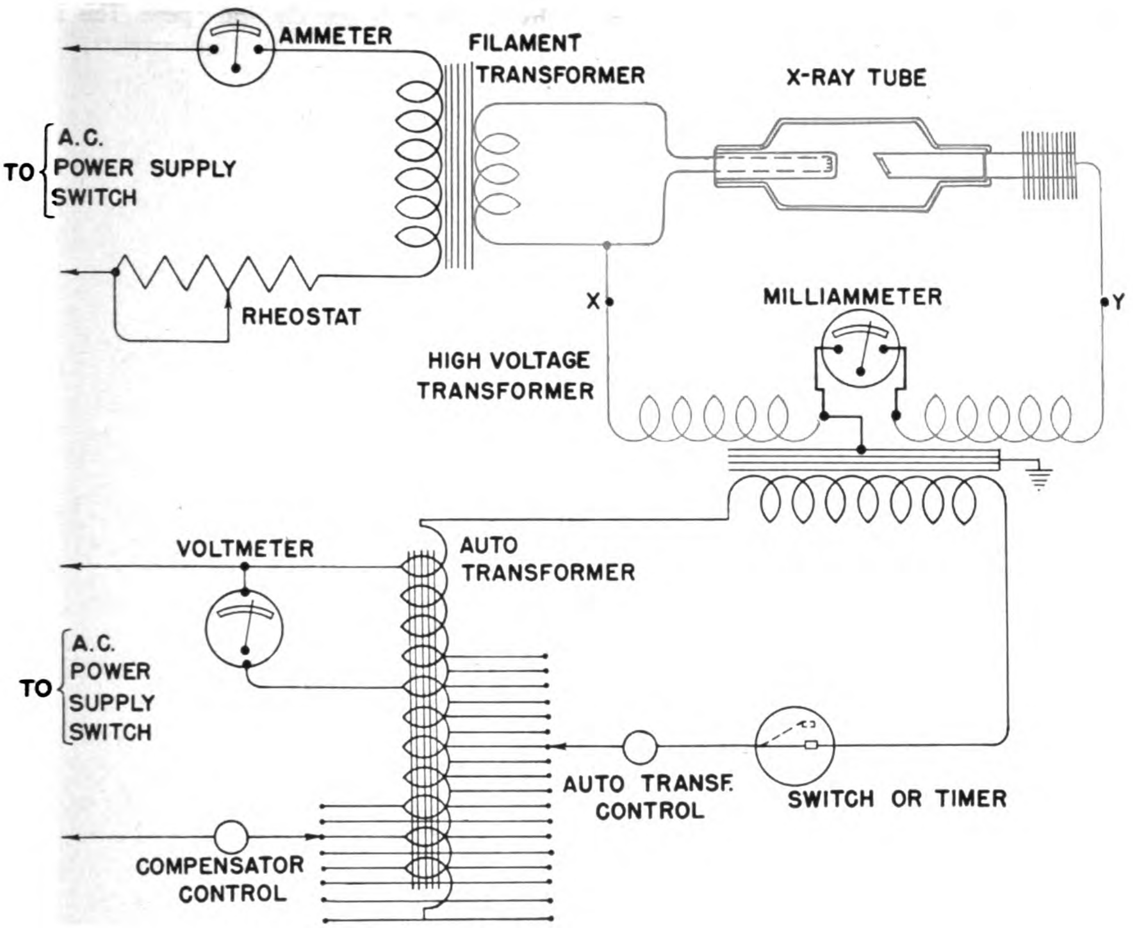


Fig. 40. Basic elements of a self-rectified circuit for the generation of x-ray.

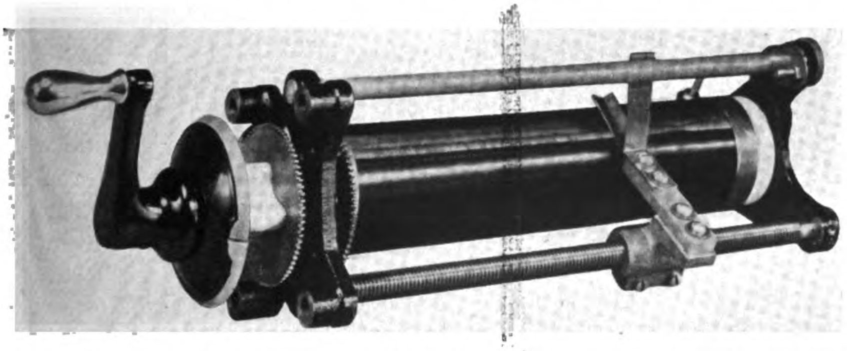


Fig. 41. Rheostat or variable resistance for controlling filament current to the x-ray tube.

almost universally used, and high-tension conductors are not accessible, the filament ammeter is made a part of the primary circuit. From what has previously been said of the importance of filament current settings in predetermining tube current, the necessity of calibrating this primary meter to read secondary amperes is recognized. The meter scale thus indicates a value several times the current actually flowing through the instrument, but with proper compensation to take care of variations in the over-all circuit of the secondary, the method is highly satisfactory and quite generally employed.

The secondary winding of the step-up transformer is connected directly across the x-ray tube, one terminal to the anode and the other to the filament circuit (cathode). The voltage across the winding will be as high as 100 kilovolts peak in a circuit of this type for diagnostic radiography, but the design is generally such that the midpoint of the secondary is grounded with the result that the ends are at a maximum of half the total voltage or 50 kilovolts peak. The primary of the transformer is controlled through the autotransformer and energized by the operation of a timing switch as indicated on the diagram. Since the ratio of transformation of the step-up transformer is fixed, secondary voltage variation is affected by varying the primary voltage over a wide range in a large number of small steps with the autotransformer control. In a typical equipment having 52 steps of autotransformer control, the total range of variation is 172 volts. With a step-up ratio of 300 to 1, each step on the autotransformer results in a change of 1000 volts, effective value, or 1.4 kilovolts peak. The circuit from the autotransformer is completed to the primary source of power through the voltage compensator control which, as has been previously described, is a selector for maintaining a fixed input voltage as indicated on the voltmeter, despite fluctuations in the supply voltage. This insures constancy of calibration, since then the autotransformer control setting will always maintain correspondence with the calibration voltage for each setting.

With the provision of a compensated line voltage, the setting of the autotransformer is an accurate indication of the x-ray tube potential when properly calibrated. Figure 42 is a typical calibration chart for a 100-milliampere generator. The chart is read quite simply by selecting the kilovolt peak value in the left or right hand column and following the figures to the column corresponding to the tube current (milliamperage) to be employed. The kilovolt selector (autotransformer) setting, can be depended upon to give the correct voltage value to an accuracy of plus or minus 2 kilovolts peak from the anticipated value. For example, if the tube current is 100 milliamperes, 70 kilovolts peak is obtained at autotransformer setting 34. For a given setting of the autotransformer, the output voltage of the high tension transformer decreases with increasing tube current. This characteristic can readily be seen from the chart in which, for example, position 34 corresponds to 70 kilovolts peak at 100 milliameperes, 75.4 kilovolts peak at 50 milliamperes, and 78.2 kilovolts peak at 10 milliamperes. This is a typical property of all transformers, the terminal voltage decreasing as the current through the secondary winding increases, and is in effect due to the increased voltage drop in the entire electrical circuit, including the high tension transformer, the autotransformer, the power line to the electric generating station, and all component connecting wires and circuit elements.

The arrangement of Figure 40 is intended merely to represent the basic elements of one of the most commonly used types of x-ray apparatus, the self-rectified circuit.

Theory of Operation, Self-Rectified Generator

With the development of the transformer, Chapter I, it was shown that its voltage output is an alternating wave of approximately the shape shown in Figure 43, in which the direction reverses at regularly recurring intervals with successive half waves of the same shape. One complete set of positive and negative values, as from A to C in the figure, is one cycle of the alternating voltage; the number of such cycles through which the voltage passes in one second is the frequency, such as 60 cycles per second. It will be recalled also that in the elementary analysis the sine wave form is used, developed from the fact that in the alternating current dynamo output, the voltage amplitude at any time is proportional to the sine function of the angle passed through by the electromotive force producing coil. Whatever distortions or variations from this theoretical form may actually be present will not affect the validity of the explanations to follow relative to the operation of the self-rectified x-ray generator.

Referring to Figure 40, it is seen that the high tension transformer secondary is connected across the x-ray tube, one terminal to the anode and the other to the cathode or filament circuit. These are shown as Y and X respectively. When the transformer primary is energized, a potential difference is established between X and Y, which varies with time as shown in Figure 43, the maximum value for which is indicated by E_{max}, commonly called the peak voltage or kilovolts peak. Considering the potential at X or Y with respect to ground, the same type of alter-

	KILOVOLT SELECTOR BUTTON						
Kv. P.	10-20 Ma.	30 Ma.	50 Ma.	60 Ma.	75 Ma.	100 Ma.	Kv. P.
33.0	1	2	3	4	5	7	33.0
34.3	2	3	4	5	6	8	34.3
35.7	3	4	5	6	7	9	35.7
37.1	4	5	6	7	8	10	37.1
38.4	5	6	7	8	9	11	38.4
39.8	6	7	8	9	10	12	39.8
41.2	7	8	9	10	11	13	41.2
42.5	8	9	10	11	12	14	42.5
43.9	9	10	11	12	13	15	43.9
45.3	10	11	12	13	14	16	45.3
46.6	11	12	13	14	15	17	46.6
48.0	12	13	14	15	16	18	48.0
49.4	13	14	15	16	17	19	49.4
50.7	14	15	16	17	18	20	50.7
52.1	15	16	17	18	19	21	52.1
53.5	16	17	18	19	20	22	53.5
54.8	17	18	19	20	21	23	54.8
56.2	18	19	20	21	22	24	56.2
57.6	19	20	21	22	23	25	57.6
58.9	20	21	22	23	24	26	58.9
60.3	21	22	23	24	25	27	60.3
61.7	22	23	24	25	26	28	61.7
63.0	23	24	25	26	27	29	63.0
64.4	24	25	26	27	28	30	64.4
65.9	25	26	27	28	29	31	65.9
67.2	26	27	28	29	30	32	67.2
68.6	27	28	29	30	31	33	68.6
70.0	28	29	30	31	32	34	70.0
71.3	29	30	31	32	33	35	71.3
72.7	30	31	32	33	34	36	72.7
74.1	31	32	33	34	35	37	74.1
75.4	32	33	34	35	36	38	75.4
76.8	33	34	35	36	37	39	76.8
78.2	34	35	36	37	38	40	78.2
79.5	35	36	37	38	39	41	79.5
80.9	36	37	38	39	40	42	80.9
82.3	37	38	39	40	41	43	82.3
83.6	38	39	40	41	42	44	83.6
85.0	39	40	41	42	43	45	85.0

FIG. 42. Typical calibration chart for a 100-milliampere radiographic generator.

nating wave describes the voltage cycle. The time at which the positive maxima occur at the two points will be one-half cycle apart. If the curve shown represents the potential of Y, which would be the reverse for X, starting at zero and increasing in a negative direction while Y increases in a positive direction, the maximum potential difference occurs at a point midway between A and B. From a previous discussion of the theory of the x-ray tube, in Chapter II, some information relative to the current flow is obtained.

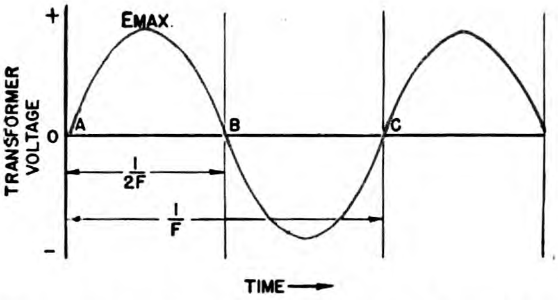


FIG. 43. Alternating voltage wave shape as obtained at transformer terminals.

It will be recalled that the negatively charged electrons emitted by the x-ray tube filament are accelerated in the direction of the anode when the latter is positively charged so that current passes through the tube only when Y is positive with respect to X. Since this condition exists only for one-half of each alternating cycle, the x-ray tube permits current flow during alternate half cycles and suppresses the current flow during the successive half-cycles. In Figure 44 is shown the variation of x-ray tube current with time, with the time scale of the latter conforming to Figure 43, which may be taken to represent the anode potential at Y. The current wave starts at zero with zero potential difference across the tube, increasing with increasing positive potential on Y to a maximum value I_{max} which occurs at the same time as E_{max}. The current then decreases, reaching zero at time B, $\frac{1}{2}F$ seconds later. The voltage on Y then increases, but with polarity reversed, to a negative maximum and falls to zero at time C.

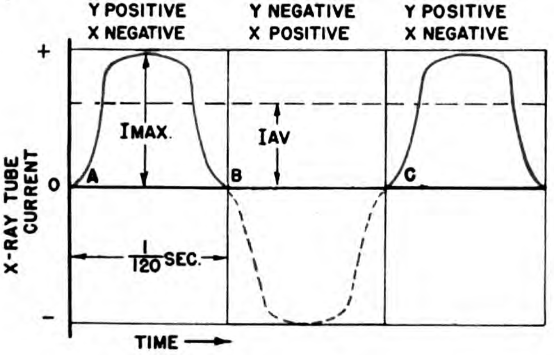


FIG. 44. Variation of x-ray tube current in a self-rectified circuit.

The tube current is blocked off by the reversed polarity and remains at zero from B to C or $\frac{1}{2}F$ seconds. At C, the cycle begins its repetition. On 60-cycle supply, these changes take place each 1/120 second, the current flowing through the the tube on alternate impulses.

It is important to note that the x-ray tube has high voltage impressed across it during the non-conducting half cycle.

Limitations of the Self-Rectified Circuit

The maximum voltage across the x-ray tube on the useful half cycle is less than on the inverse non-conducting half cycle. The reason is that under conditions of load, voltage drops occur in the secondary and primary of the high tension transformer, in the autotransformer, and in the line supplying power which reduces the available voltage to the x-ray tube. For example, with the useful voltage of 85 kilovolts peak, the inverse voltage might be 120 kilovolts peak. The equipment and x-ray tube would then have to be designed to withstand the stress of the higher voltage and would, as a result, be larger and heavier than if it could be designed for 85 kilovolts peak. The magnitude of this difference between useful and inverse voltage increases with the milliamperage output of the transformer. Obviously this is a limitation of the use of self-rectified equipment. In practice, 100 milliamperes is the upper limit commonly set for radiographic machines. Further mention will be made of this fact in a later section, page 46, on the "Inverse Reducer."

A second limitation to the use of a self-rectified circuit is that it limits the energy rating of an x-ray tube. There are two reasons for this: the danger of reverse current in the x-ray tube, that is, from the anode to the cathode, and the high peak current and consequent focal spot temperature for a given average milliamperage.

If the focal spot of the anode is heated to a temperature high enough to emit electrons, keeping in mind that it, like the filament, is made of tungsten, these electrons will be accelerated in the reverse direction on the inverse half cycle. The filament will then be bombarded by high speed electrons, and its temperature raised beyond the value fixed by the filament current.

An x-ray tube can be completely destroyed by operation under conditions of inverse emission, for inverse current may cause damage to the filament or a portion of the cathode focusing cup, which has a much lower melting point than the tungsten filament itself. It is essential then to limit the operating temperature of the focal area to a point well below that at which destructive electron emission takes place, the reduction being necessitated by the fact that the voltage across the tube reverses itself each half cycle. The current-carrying capacity of a given focal area is thus limited to a value substantially less than that which would be permissible if no reversal took place.

For a given average tube current, the peak value of current and the resultant peak of focal spot temperature is higher on a self-rectified generator than it is on a power supply in which both halves of the voltage wave are utilized. Tube ratings are based on the average current as read on a milliammeter of the direct current D'Arsonval type of milliammeter. Such a meter is so constructed that the coil which deflects the pointer assumes a position directly proportional to the average value of the current over any number of cycles. The coil moves in a uniform field with a uniform gradiant of the restraining forces so that the torque acting on the moving element is, at any instance, proportional to the instantaneous value of the current in the coil. The mass of the moving system is sufficiently great, however, that with rapid pulsation, as in Figure 44, the coil will assume a constant deflection which is directly proportional to the average value of the current. Referring to Figure 44, the full cycle extends from A to C of time duration 1/60 second on 60-cycle current. The instantaneous value of the deflecting part of the meter follows the current variation from A to B and falls to zero from B to C. The meter pointer, however, assumes a constant position that is considerably less than the maximum value I_{max} which actually flows through the circuit.

The ratio can be calculated, assuming a sine wave of current for the half cycle AB. The average value of a half cycle is

$$I_{av} = \frac{2}{\pi} I_{max} = 0.636\ I_{max}$$

From B to C, the current value is zero and the time is the same as that for the half cycle A-B. The average value for the entire cycle, then, is,

$$I_{av} = \tfrac{1}{2} \times \frac{2}{\pi} I_{max} = 0.318\ I_{max}$$

$$\text{or} \quad I_{max} = 3.14\ I_{av}$$

The maximum value of current is approximately three times the average value as read on the milliammeter for a self-rectified circuit. The x-ray tube focal area must then be sufficiently large to withstand an instantaneous current of more than three times the indicated value. Since the x-ray output is proportional to the average current and the temperature more nearly proportional to the maximum, it can be recognized that the unused half cycle reduces directly the permissible x-ray output per square millimeter of focal area.

If both halves of the voltage wave, A-B and B-C of Figure 43 could be utilized, the ratio of maximum to average current would be:

$$I_{max} = 1.57\ I_{av}$$

so that the focal area of the tube would be required to withstand a maximum instantaneous value of less than twice the average value as read on the milliammeter. Since meters read average values and tube ratings are therefore expressed in terms of average current, it is to be expected that the ratings for identical focal areas,

		1/10 Sec.	*1/2 Sec.*	*5 Sec.*	*10 Sec.*	*30 Sec.*	*Fluoroscopic*
4.5 mm.²	SELF-RECTIFIED	115 MA.	90 MA.	60 MA.	50 MA.	35 MA.	5 MA.
	FULL-WAVE	230 MA.	175 MA.	95 MA.	72 MA.	45 MA.	5 MA.
2.0 mm.²	SELF-RECTIFIED	35 MA.	32 MA.	27 MA.	25 MA.	20 MA.	5 MA.
	FULL-WAVE	70 MA.	58 MA.	40 MA.	35 MA.	25 MA.	5 MA.

FIG. 45. Table showing comparative ratings on self-rectified and full-wave rectified circuits for focal spots 4.5 millimeters and 2.0 millimeters.

even without the limitation of inverse emission, will be substantially less for the self-rectified circuit than they might be for a generator in which the anode potential remains positive for both half cycles of voltage. Figure 45 lists comparative ratings on self-rectified and full-wave rectified operation for focal spots of 4.5 mm^2 and 2.0 mm^2, the values being taken at 80 kilovolts peak, single phase, 60 cycles. It is seen that for the very short exposures of 1/10 to ½ second, the ratio of current ratings is approximately two to one. For the longer exposures, the heat capacity and radiating ability of the entire anode tend to average out the pulsations in energy input to the tube. The 30-second ratings, for example, are different by only 20 per cent, while the long time fluoroscopic ratings are the same for a given tube design regardless of type of circuit and, within very broad limits, the focal area itself.

It follows that for comparable current ratings, a tube operated on a self-rectified circuit will require a larger focal spot than one operated on a full-wave rectified circuit. Figure 46 is a set of comparative focal spot sizes for the same current rating on 60-cycle, single-phase generators, the time values for the comparison being arbitrarily selected as 1 second. It is evident that from the standpoint of detail sharpness in the radiograph there is preference for a 2.8 mm^2 focal spot in comparison to its self-rectified equivalent, 4.5 mm^2, or for a 2.2 mm^2 focal spot over one of 3.5 mm^2. There is, however, a factor of critical unsharpness which acts to make these differences less objectionable than one might suppose on casual examination, but which more definitely sets the upper limit of focal area beyond which sharpness of the image rapidly becomes unacceptable. To make this point clear, a 100 milliampere self-rectified generator will usually be operated in conjunction with a tube whose large focal spot is approximately 4.5 mm^2, maximum rating 85 kilovolts peak, 100 milliamperes, 2/10 second. A full-wave rectified unit would require for comparable rating and output, a 2.8 mm^2 spot which would produce a visibly sharper radiographic image, all other factors remaining fixed. If, however, it were desired to operate a 200-milliampere generator self-rectified, the focal spot required would be at least 6.0 mm^2, a quite unsatisfactory combination. The resultant image would be so lacking in sharpness that it would be far less satisfactory than that obtained with a 4.5 mm^2 focal spot in twice the time of exposure. By such considerations, the upper practical limit for self-rectified generators is established, as is the lower limit for full-wave rectifiers, beyond which no economic justification exists for the small gain in detail sharpness. At present, the largest self-rectified diagnostic unit has a rated capacity of 100 milliamperes at 85 kilovolts peak; for higher current ratings, the rectified circuit is employed. The self-rectified circuit is also extensively employed in x-ray generators for deep therapy and industrial radiographic applications in which the voltage rating is 200 kilovolts peak, 220 kilovolts peak, 400 kilovolts peak, and 1000 kilovolts peak, the currents being 15 milliamperes or less.

Self-Rectified	*Full-Wave*
2.0 mm.^{2}	1.3 mm.^{2}
3.5 mm.^{2}	2.2 mm.^{2}
4.5 mm.^{2}	2.8 mm.^{2}
4.9 mm.^{2}	3.2 mm.^{2}
5.2 mm.^{2}	3.4 mm.^{2}

FIG. 46. Table showing comparative focal areas for the same ratings on full-wave rectified and self-rectified circuits.

Valve Tube (Kenotron) Rectification

In discussing the theory of operation of the self-rectified x-ray generator, the limitations imposed by inverse voltage and form factor of the current wave were shown to lead to:

1. Requirements of focal areas larger than those which could be employed if both half waves of the alternating current cycle were utilized.
2. The establishment of a practical limit beyond which increased tube capacity would not be accompanied by improvement in detail sharpness of the radiograph, the focal area unsharpness increasing at a greater rate than the improvement effected by reduction in exposure time.

Modern generators for radiographic applica-

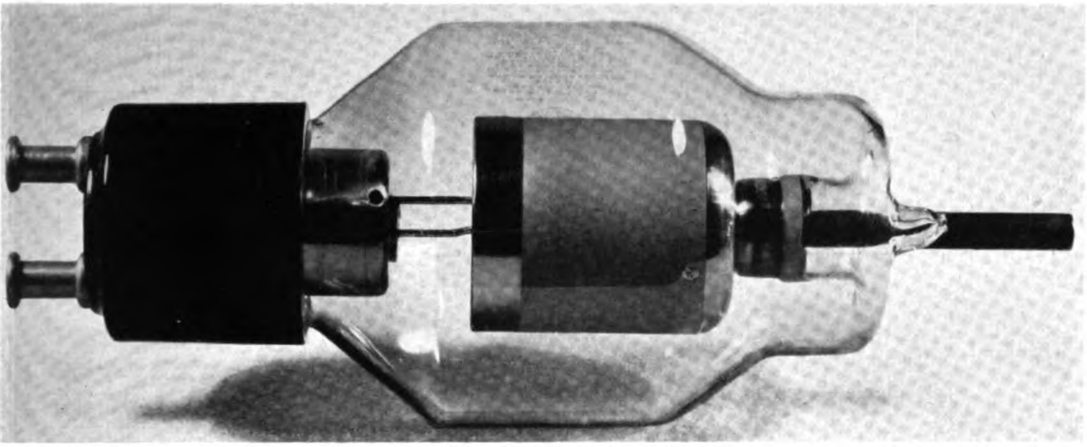


FIG. 47. Kenotron rectifying tube designed for oil-immersed operation, maximum rating 140 kilovolts peak.

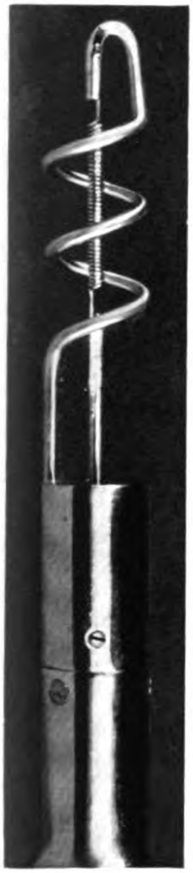


FIG. 48. Cathode structure of a kenotron rectifying tube showing tungsten filament and supporting spiral.

tions with a capacity of more than 100 milliamperes are mainly full-wave rectified units, employing four high-voltage hot-cathode rectifier tubes.

Figure 47 is a photograph of a rectifier tube (kenotron) designed for use in 200 and 500 milliampere radiographic generators with a maximum voltage rating of 140 kilovolts peak. The kenotron consists of a cylindrical anode which surrounds a co-axial tungsten filament, Figure 48, supported by a heavy molybdenum spiral which forms part of the tube filament circuit. The tube is highly evacuated, requiring the same type of preparation and exhaust procedure as is applied to the x-ray tube.

Like the x-ray tube, the kenotron is a two-element hot-cathode tube which conducts current by means of electron emission from the tungsten filament. It differs from the x-ray tube, however, in the conditions of operation. The x-ray tube operates with a high voltage drop, the tube current being limited by the emission from the filament, an increase of filament temperature being accompanied by a great increase in tube current, as shown in Figure 24. The current is "emission limited" under which conditions the voltage drop may be made sufficiently high to produce x-rays of any desired wavelength.

The kenotron tube is operated with very high emission from a heavy filament of large surface area operating at high temperature, as indicated in Figure 49. The space charge is reduced to a

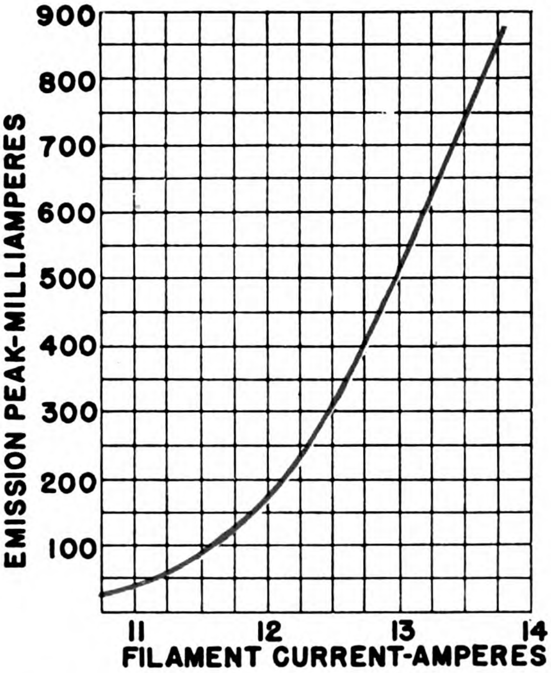


FIG. 49. Emission characteristic for a kenotron tube.

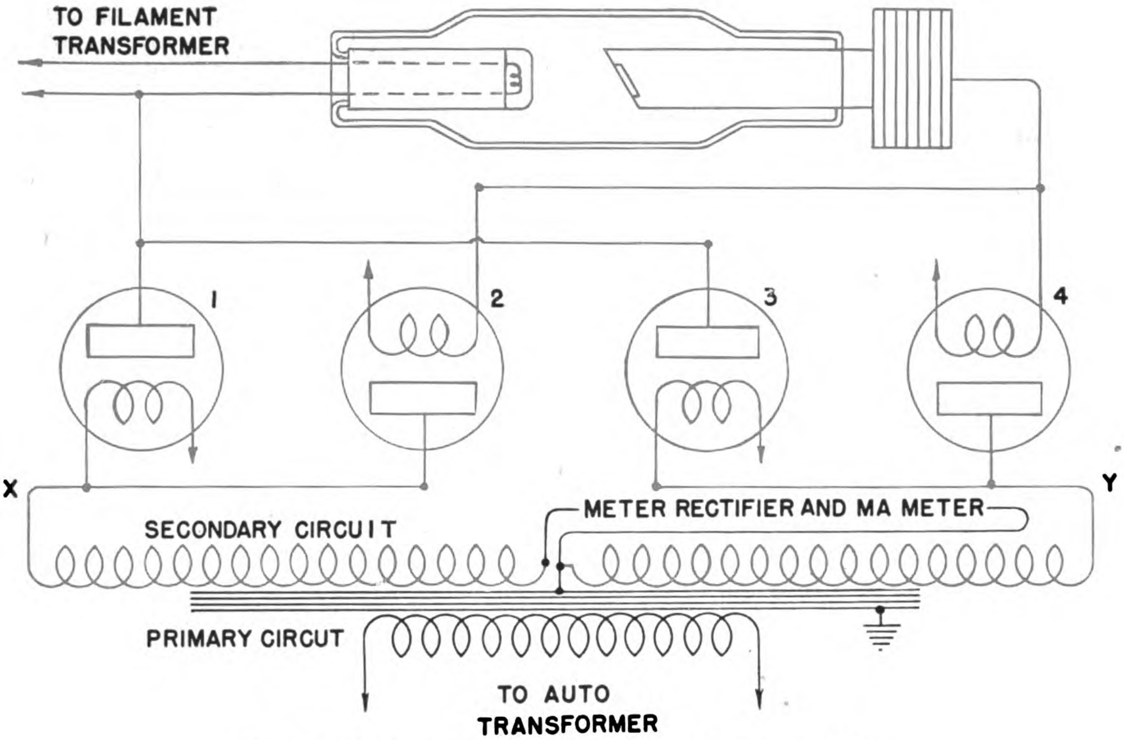


FIG. 50. Basic circuit for a bridge type full-wave kenotron rectifier.

minimum by employing an anode of large surface completely surrounding the kenotron cathode. So designed, the voltage drop across a single kenotron supplying full load current to a 500-milliampere x-ray tube is about 3 kilovolts peak. Such a tube operates so that the current through it is "space-charge limited" and must always have sufficient electron emission to insure that more than the number necessary to supply the x-ray tube load are available. Under any other circumstances the kenotron will be emission limited and dissipate energy of electron bombardment in its anode beyond the capacity of the tube, resulting in its damage or destruction.

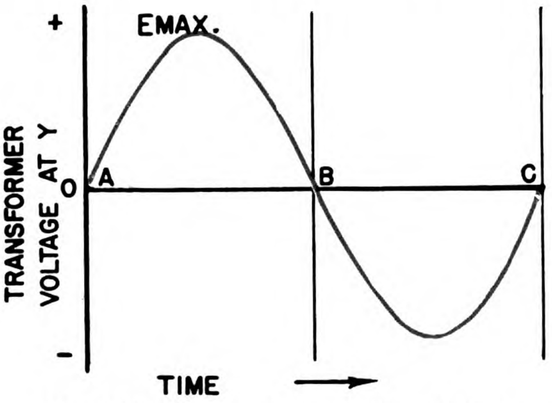


FIG. 51. Transformer voltage variation with time.

The Full-Wave Kenotron Rectifier

The operating principles of the full-wave kenotron rectifier are illustrated in Figures 50, 51, and 52. Four kenotron tubes are shown in what is called a "bridge" arrangement, the type most frequently used in x-ray practice. In the interest of simplicity, only the necessary elements of the circuit are shown with the understanding that the kenotron and x-ray tube filaments are energized from insulated step-down transformers of the type already discussed, that some form of current indicating meter is connected at the point M in the transformer secondary, and that the necessary switches and controls are part of the primary circuit.

The kenotron, like the x-ray tube, conducts current only when the anode is positive with respect to the cathode. When the reverse is true, the tube is no longer conducting, acting as an "open" in the circuit. Consider that the voltage wave, Figure 51, corresponds to the po-

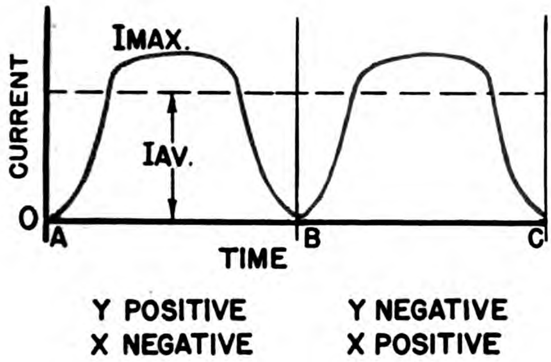


FIG. 52. X-ray tube current variation with time.

tential to ground of the transformer terminal Y in Figure 50. This sine wave of alternating voltage has already been discussed in a previous section on the self-rectified circuit where may be found further explanation regarding the nature of its variation with time. Refer to Figure 43 and Figure 44 on page 36.

With terminal Y positive with respect to ground or zero potential, X will be negative by an equal voltage. From Figure 50 it is seen that the anode of kenotron No. 4 and the cathode of kenotron No. 1 are connected to the highest positive and the lowest negative points in the circuit. Under these conditions current will be conducted through these tubes which, because they operate with very little voltage drop, bring potential Y to the anode of the tube and X to the cathode. Essentially the full transformer voltage is thus applied to the x-ray tube with correct polarity. During this time (A to B, Figure 52) current flows through the x-ray tube, kenotron No. 1 and kenotron No. 4. The remaining two kenotrons are not conducting current because the anode of No. 2 is negative with respect to its cathode and the cathode of No. 3 is positive with respect to its anode. The full transformer voltage is impressed across each of these tubes.

During the next half-cycle the potential of Y is negative with respect to ground; X is positive. Kenotrons No. 1 and No. 4 are no longer conducting because of the reversal of potential on their elements, but with X positive, kenotron No. 2 conducts current to the anode of the tube, and with Y negative, kenotron No. 3 completes the circuit from the cathode of the x-ray tube. During this half-cycle, B to C in Figure 51, the potential across the x-ray tube is of the same polarity as that during the previous half-cycle, so that the current variation is a repetition as shown from B to C in Figure 52. On this half cycle, kenotrons No. 1 and No. 4 are non-conducting, each with practically full voltage impressed across them.

Since both half-cycles have been utilized, the current is full-wave rectified and the voltage across the x-ray tube varies in magnitude only, the direction remaining constant. The ratio of maximum to average tube current, assuming a sine wave, is:

$$I_{max} = \frac{\pi}{2} = 1.57\ I_{av}$$

It will be recalled that for a self-rectified circuit the relation is:

$$I_{max} = \frac{2\pi}{2} = 3.14\ I_{av}$$

The significance of these ratios with reference to tube ratings has been previously discussed.

For a given maximum value of current, the average direct current value of the full-wave rectified current is twice that of the half-wave; the root-mean-square alternating current value is 1.41 times as great full-wave as half-wave.

The full-wave kenotron rectified system described above can be incorporated into a circuit such as that of Figure 40 to produce a practical x-ray generator. Since the rectification reduces the ratio between the peak current and average current in the transformer winding as well as in the x-ray tube, the transformer likewise can be rated at a higher current output. Thus, if the unit represented in Figure 40 is a 100 milliampere self-rectified unit, it can be rated at 200 milliamperes with the addition of four kenotrons connected as shown in Figure 50. If any of the components of the former are limited in capacity by their peak inverse voltage rating, the addition of the rectifier will raise the maximum operable voltage by an amount corresponding to the difference between the inverse and useful voltage limit. For example, the high voltage shockproof cables which connect the x-ray tube to the transformer are limited to a maximum rating of 50 kilovolts peak inverse on each cable. Under these conditions, the useful voltage is approximately 45 kilovolts peak; the maximum voltage rating of the generator is then

90 kilovolts peak. The full-wave rectifier operating from the same transformer permits a maximum rating of over 100 kilovolts peak since the cables operating on direct current can each be subjected to well over 50 kilovolts peak.

Figure 53 is the interior of a 500-milliampere transformer and full-wave rectifier designed for operation at a maximum of 140 kilovolts peak. The high-tension transformer, kenotron filament transformers, and x-ray tube filament transformers are clearly shown. The kenotrons are mounted in the receptacles directly above the transformers. (The kenotrons are not shown in the illustration.)

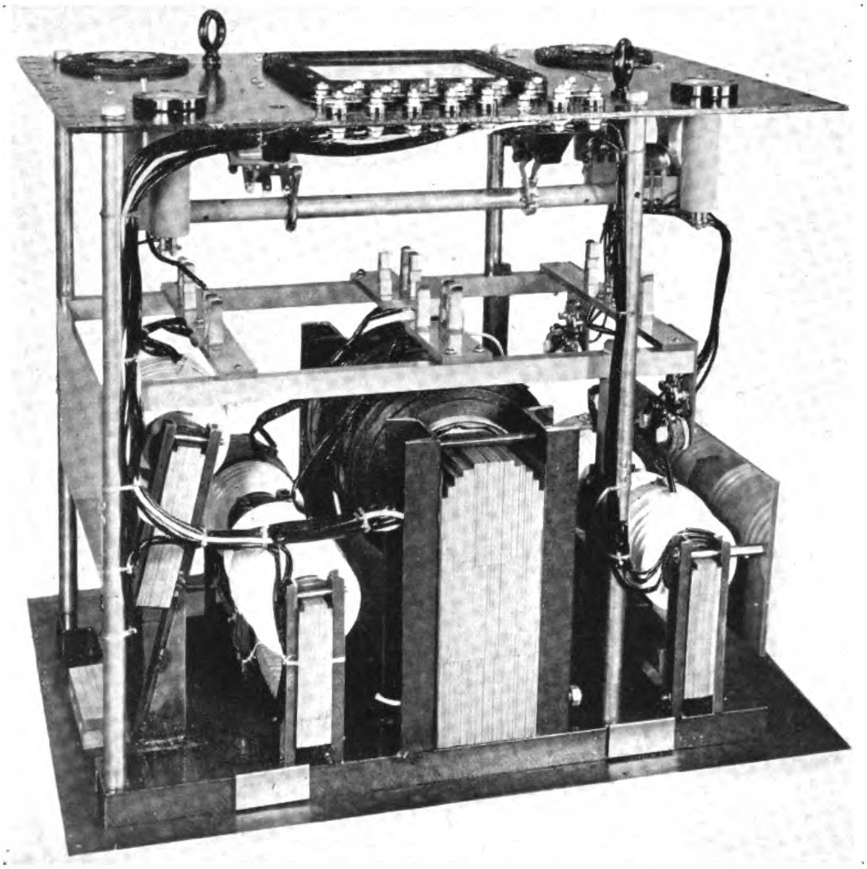


FIG. 53. Transformer and full-wave rectifier for a 500-milliampere generator.

The Half-Wave Kenotron Rectifier

From the preceding explanation of the operation of the full-wave rectifier, it is readily seen that a pair of kenotrons are connected in series with the x-ray tube and the high-tension transformer in such a direction as to permit the passage of current on both half cycles. If only one set is used, as No. 1 and No. 4 of Figure 50, there results a type of circuit known as a half-wave rectifier which, though not utilized in diagnostic medical apparatus, is of some importance as a mobile 140 kilovolts peak unit for superficial therapy using a shockproof tube with high voltage shockproof cables. Referring to Figures 50 and 51, the operation of a two-kenotron half-wave rectifier can be described. It is assumed that kenotrons No. 2 and No. 3 have been removed and are no longer a part of the circuit.

With terminal Y positive and X negative, current is conducted through the kenotrons No. 1 and No. 4 to bring the potential of Y to the anode and that of X to the cathode of the x-ray tube.

On this half-cycle, current flows through the x-ray tube as has been previously described.

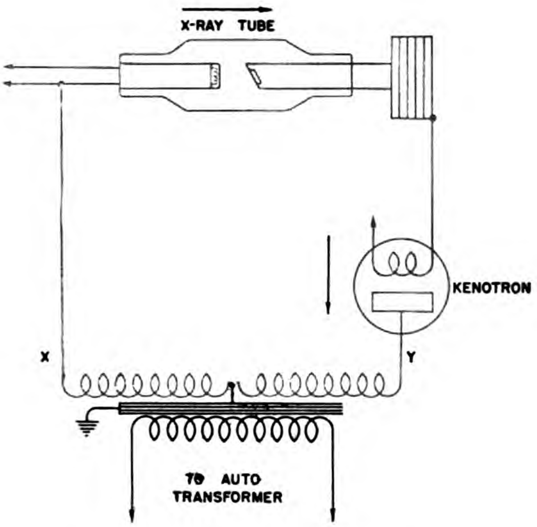


FIG. 54. Single kenotron half-wave rectifier, as used in radiographic x-ray generator.

During the next half-cycle, the potential of Y is negative with respect to ground and X is positive. The polarity is now such that kenotrons No. 1 and No. 4 are non-conducting and the inverse transformer voltage is applied across the two kenotrons in series with the x-ray tube so that only a fraction of the full voltage exists across the latter. Under these conditions, the problem of inverse current is practically eliminated so that the operating temperature of the focal area may be permitted to be substantially higher than is the case on a self-rectified circuit, resulting in an increase in tube rating for a given focal area in comparison to the self-rectified rating. Furthermore, the shockproof cables are not subjected to alternating voltage, a fact which permits a higher rating and, finally, they are not required to withstand an inverse voltage higher than the useful voltage across the x-ray tube on the conducting half-cycle.

A now obsolete form of radiographic generator utilized a single kenotron in a half-wave rectified circuit as shown in Figure 54. The x-ray tube passes current when point Y is at positive potential with respect to ground, since the kenotron then is a conducting valve. On the succeeding half-cycle, with Y negative, the inverse transformer voltage is impressed across the x-ray tube and kenotron in series, similar to the situation described previously for a two-kenotron rectifier except that only one rectifier is in the circuit. The focal spot rating of both circuits is the same since in neither case does the x-ray tube have a high inverse voltage impressed across it. With the single kenotron half-wave rectifier, however, the cathode side of the circuit has an alternating voltage existing so that if shockproof cables were used the voltage limitation of the cathode cable would be the same as its alternating current rating.

Comparative energy ratings for half-wave rectified and self-rectified circuits are given in the table, Figure 55. The difference is due to the fact that the focal spot in the former case can be operated at a higher temperature since a certain amount of electron emission from the target will produce no destructive effects.

	1/10 Sec.	*½ Sec.*	*5 Sec.*	*10 Sec.*	*30 Sec.*
HALF-WAVE	160 MA.	125 MA.	75 MA.	62 MA.	40 MA.
SELF-RECTIFIED	115 MA.	90 MA.	60 MA.	50 MA.	35 MA.

FIG. 55. Comparative ratings for a 4.5 mm. focal spot, half-wave rectified and self-rectified circuits.

X-Ray Apparatus

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General Description of Shockproof Apparatus

Developments in the field of x-ray apparatus have been in the direction of more powerful equipment with decreased size and weight. The need for electrical protection from dangers of shock to the patient and operator have become increasingly important as the transformers have become more powerful and efficient. The need for roentgen-ray protection is equally important, but a discussion of this subject will be found in Chapter VII. Modern x-ray apparatus is protected from electrical hazards by one of two methods:

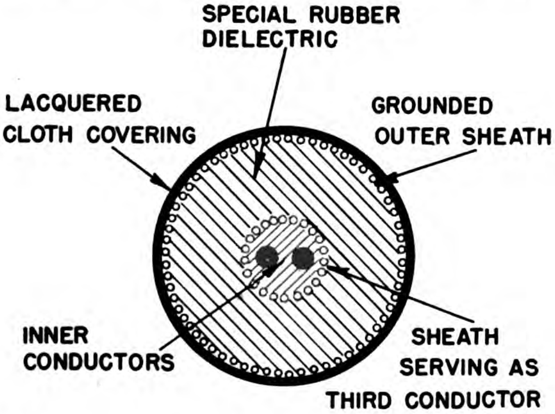

Fig. 56. Cross-section of a flexible high voltage cable used for connection between a high voltage generator and a shockproof x-ray tube casing.

1. The use of a shockproof and x-ray protective tube casing with connections to the high tension transformer and rectifier being made by special high voltage cable.
2. Single unit type oil-immersed equipment in which the x-ray tube, high voltage transformer, and filament transformer are placed together in a single oil-filled container or, in the case of 1000 kilovolts peak apparatus, a single gas-filled container.

Figure 30 is a shockproof tube casing in which the x-ray tube is oil-immersed. Connections to the tube are made by means of the flexible high voltage cable, a cross-section of which is shown in Figure 56. The high tension conductors are surrounded by special rubber compounds which have excellent insulating properties. The rubber is surrounded by a flexible metallic sheath which is connected to ground potential. The ends of the cable are fitted with plug-in type bushings which make connection to the x-ray tube and to the high-voltage generator.

With the shockproof tube casing and flexible high voltage cable, the transformer can be placed at some distance from the tube and the entire electrical circuit is protected from high voltage. The tube-supporting mechanism over the x-ray table is required only to provide support and flexibility to the x-ray tube and its small container. This type of apparatus is employed usually for x-ray machines of 100 milliampere capacity and over, self-rectified and full-wave rectified.

The Single Unit Type Self-Rectified X-Ray Generator

In some types of apparatus, it is desirable to immerse the x-ray tube in the same oil-filled container which includes the filament and high tension transformers as shown in Figures 57 and 58. This is a 25-milliampere, 85-kilovolts peak machine used as a mobile unit or as a conventional combination radiographic and fluoroscopic generator in conjunction with an x-ray table. The high voltage leads to the tube are completely enclosed and protected. The low voltage conductors from the control stand are brought into a terminal block on one side of the casing and provide no interference to free manipulation of the self-contained unit on its counterbalanced supporting structure.

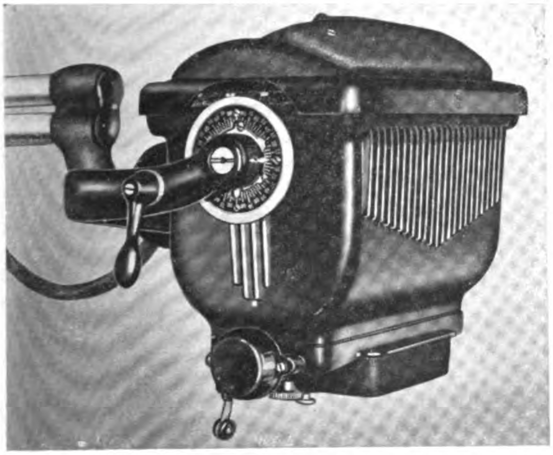

FIG. 57. Unit type self-rectified x-ray generator rated at 85 kilovolts peak.

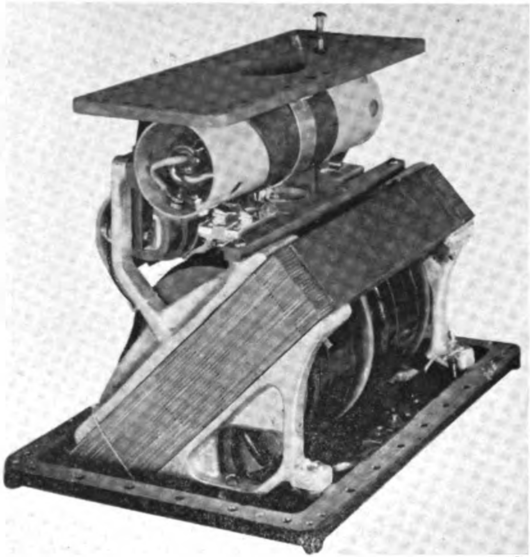

FIG. 58. Interior of unit type self-rectified x-ray generator.

The same type of assembly is utilized for low power portable units and for dental x-ray machines where the weight of the transformers does not seriously limit the flexibility of the head. With the development of x-ray tubes capable of operating on a self-rectified circuit from 100 to 200 kilovolts peak, the unit type of equipment has become widely used in therapy and industrial radiography. For these, specially designed supporting structures, often motor-driven, are used to obtain the desired flexibility. Figure 59 is a 220-kilovolts peak self-contained unit used for deep therapy mounted on a motor-driven suspension which raises, lowers, and rotates the unit on two axes.

An important part of the unit type apparatus, whether it be a 400-kilovolts peak, 5-milliampere therapy or an 85-kilovolts peak, 25-milliampere radiographic apparatus is the inverse reducer, a device connected in the primary circuit of the high tension transformer for the purpose of limiting the rise in voltage across the secondary terminals on the non-conducting or inverse half cycle, B to C, Figure 44. Since the x-ray tube passes current only on the half-cycle, A to B, the actual voltage produced in the transformer secondary, from B to C, will increase by the amount of the voltage drop caused in both sec-

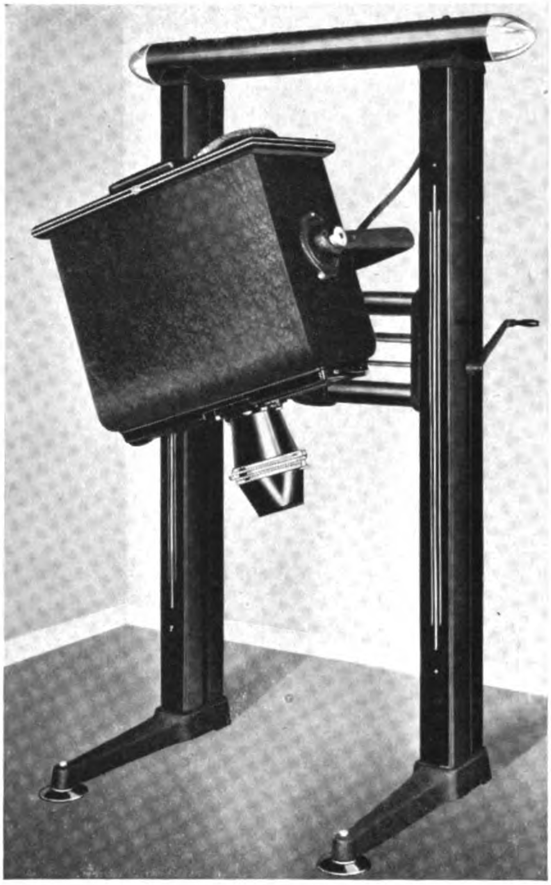

FIG. 59. 220 kilovolts peak self-contained unit type x-ray generator.

ondary and primary windings by the secondary tube current and the primary current necessary to supply the power loss in the tube.

The difference may be as much as 30 kilovolts peak for a circuit operating at 70 kilovolts peak on the useful half cycle so that additional insulation and clearances are necessary within the container to withstand 100 kilovolts peak. Thus the size and weight of the unit would be appreciably increased with no gain in its rating.

Figure 60 is a diagram of the inverse reducer circuit, consisting of a special low-voltage rectifier tube known as a "tungar" which has connected across it a fixed resistance unit, the combination being connected in series with the primary winding of the high tension transformer. The tungar tube is a two-element gas-discharge hot-cathode tube. In order to reduce the voltage necessary to make the tube a good conductor, the space charge around the cathode is greatly reduced by the introduction of argon gas to a pressure of a few centimeters. Positive ions are then produced by the impact of electrons with the gas molecules present and the negative space charge is neutralized to the extent that a current of 10 amperes can pass through the tube with a voltage drop of less than 10 volts.

The operation of the inverse reducer can be followed by reference to the diagram. The arrows show the direction of electron flow in the primary and secondary circuit for the useful half cycle of operation during which the anode of the x-ray tube is positive with respect to the cathode. The tungar is so connected that during the useful half cycle it conducts practically the full primary current. On the next half cycle, the x-ray tube becomes non-conducting as does the tungar tube, but the voltage produced in the secondary winding is limited to an inverse kilovolts peak which is practically the same as the useful kilovolts peak. The high voltage transformer has a secondary winding with appreciable distributed capacity by virtue of the large number of turns and the small distance between them. With the aid of electric circuit analysis which is beyond the scope of this work, it can be shown that on the half cycle when the low voltage rectifier tube partially disconnects the transformer from the line, part of the transformer's charging current is supplied from its own secondary capacity current. As a result the inverse voltage is distorted in wave shape and the transformer is isolated from the line voltage rise. The inverse voltage, under these conditions, does not rise to more than 1 or 2 kilovolts peak over the useful. The insulation problems are greatly reduced as a result and the over-all size and weight of the unit type x-ray generator is substantially less than it might be if the maximum peak inverse voltage were allowed to rise 30 kilovolts peak over the useful. Since the inverse reducer is in the primary circuit, it is generally mounted in the control cabinet and does not contribute to the weight or bulk of the x-ray tube and its associated transformers.

The Full-Wave Rectified X-Ray Generator

In a previous section the essential elements of the simplest form of x-ray generator, the self-

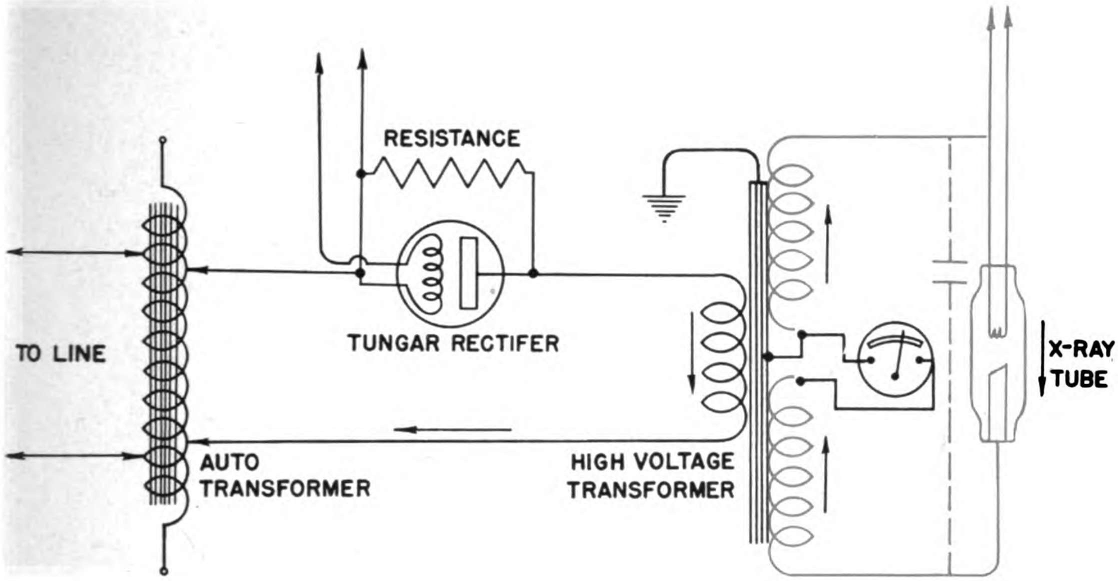

FIG. 60. Schematic diagram of a self-rectified generator with inverse reducer circuit.

rectified circuit, were briefly described in conjunction with Figure 40. In this section, the elements for such a circuit to include all the necessary elements of a modern 200 milliampere full-wave rectified x-ray machine, will be discussed. In addition to the constituents previously given for a self-rectified generator, there will be the following:

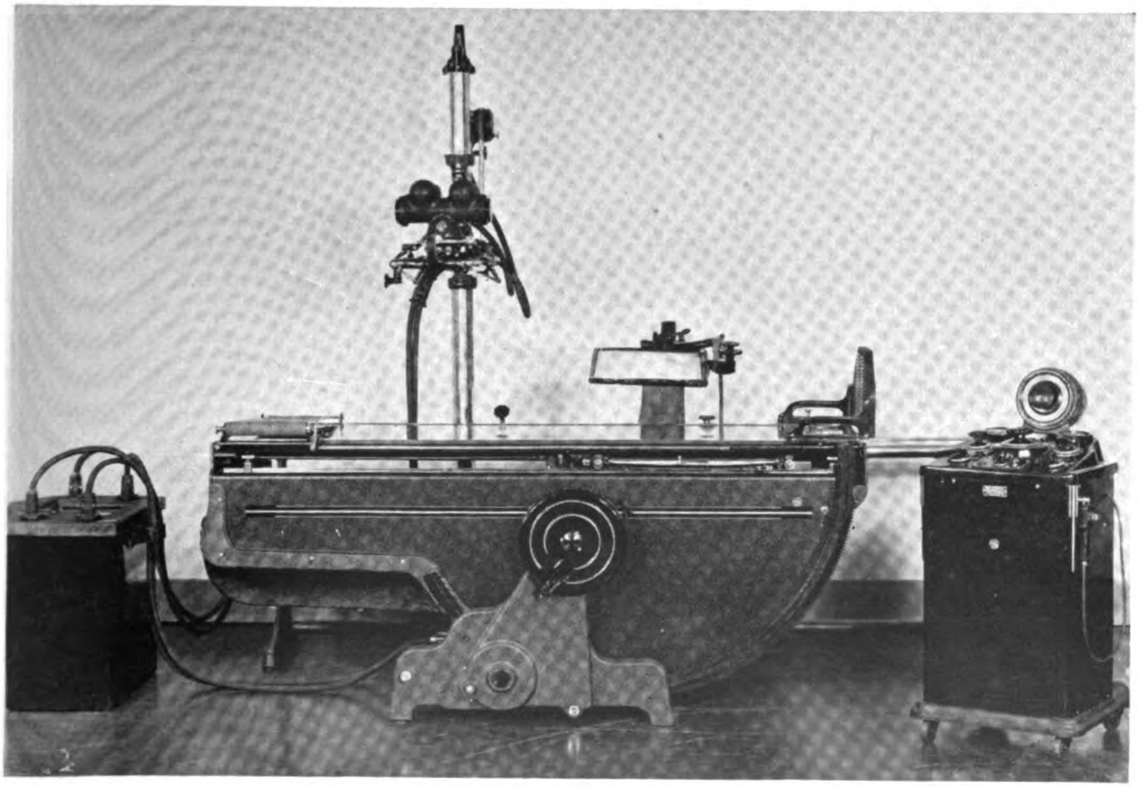

FIG. 61. Complete 200-milliampere full-wave rectified unit with radiographic and fluoroscopic tube.

1. Filament heating transformers for energizing the rectifier tubes.
2. A booster transformer which maintains constant kenotron filament temperature despite the drop in line voltage with the application of power to the x-ray tube.
3. A meter rectifier connected in the milliammeter circuit to rectify the alternating current which should be indicated by a meter connected at the point M in Figure 50.
4. A kenotron indicator which is automatically illuminated if one of the rectifying tubes ceases to function, preventing unsuspected operation of the generator as a half-wave rectified unit.
5. A switch, incorporated in the control apparatus which changes the kenotron filament voltage to increase emission for high milliampere technic.

Figure 61 shows a complete 200-milliampere full-wave rectified unit including the high tension transformer and rectifier unit, the shockproof cables and x-ray tube, and the control apparatus. Figure 62 is a close-up of the control panel, Figure 63 is the interior, and Figure 64 is a circuit diagram for such an x-ray generator and its control. In the discussion to follow, the elements described can be located on the circuit diagram and on the control panel by reference letters, as A, B, C, etc.

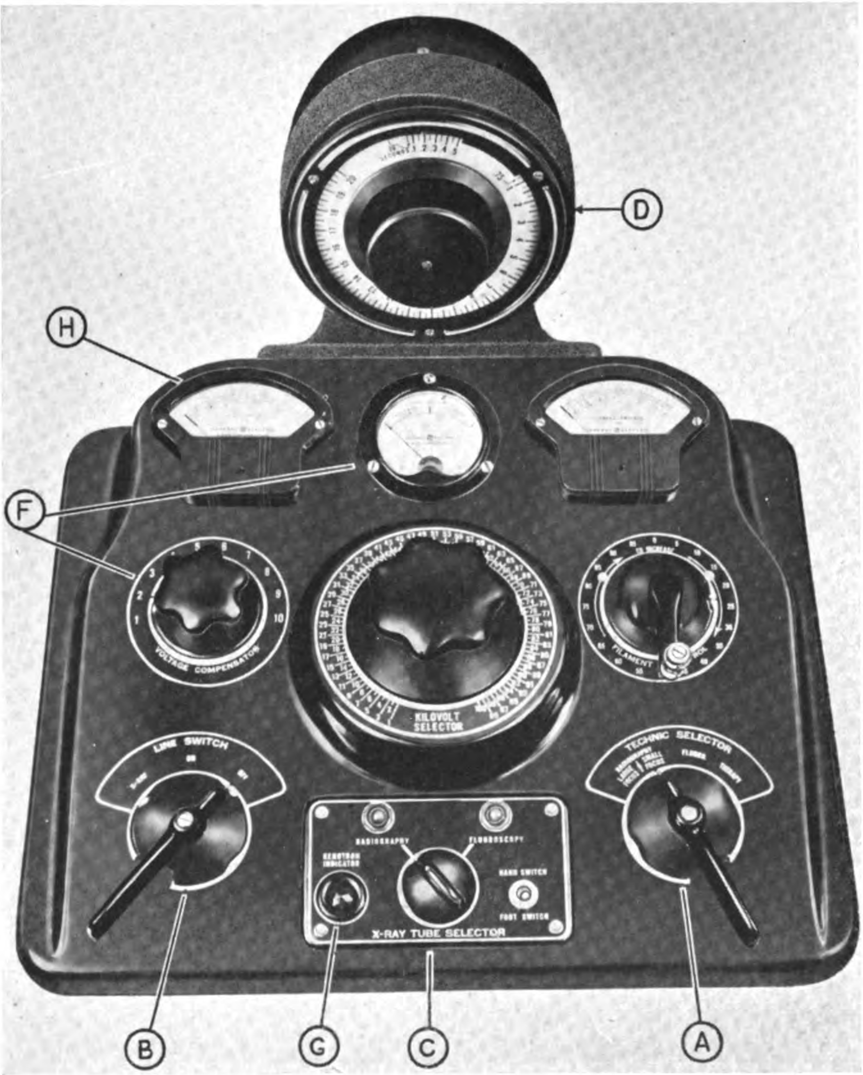

FIG. 62. Control element for a 200-milliampere full-wave rectified unit.

The Technic Selector (A)

A switch assembly "A", Figure 62, known as a "technic selector," (TS), is incorporated in the control apparatus to coördinate the following operations:

TS-1 Connects resistance into the primary of the high-tension transformer when it is used for fluoroscopy or superficial therapy technics, and shorts out the resistance for radiography.

TS-2 Selects one of the two filaments in a double-focus type of x-ray tube.

TS-3 Changes the kenotron filament voltage to increase its emission for high milliamperage technic.

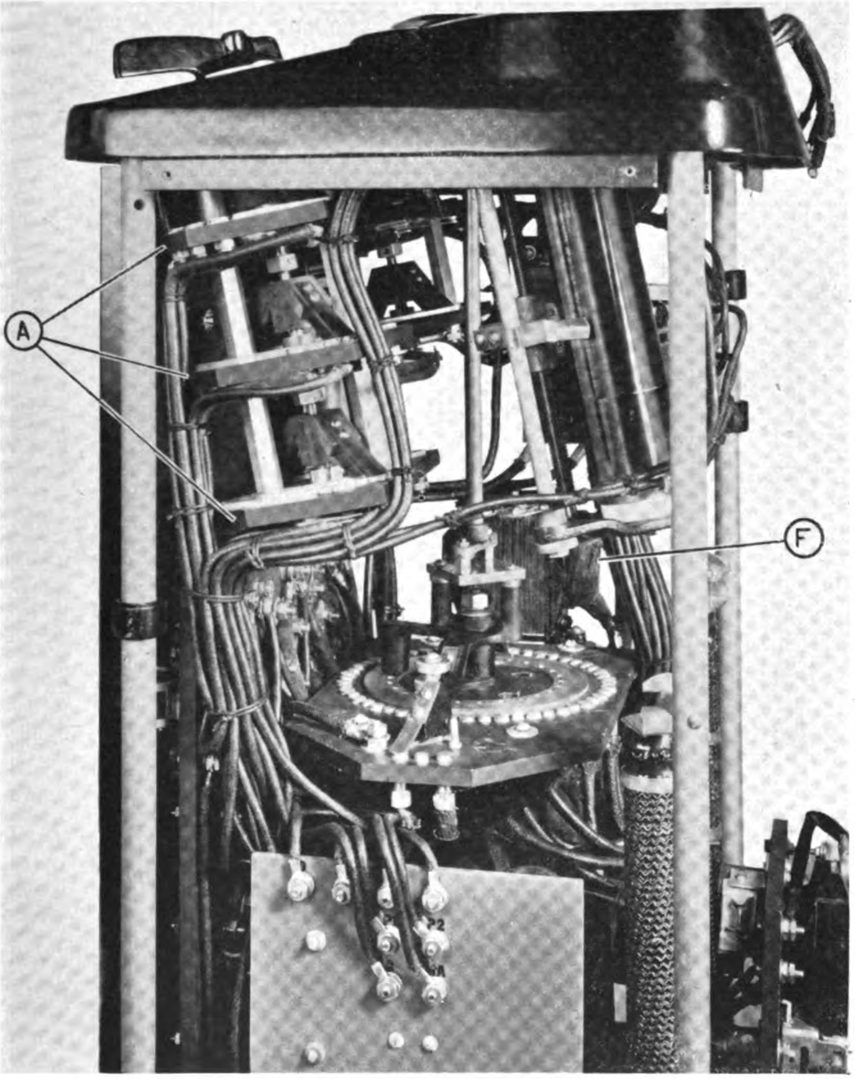

Fig. 63. Interior of control cabinet, 200-milliampere full-wave rectified unit.

TS-4 Disconnects exposure timing switch for the procedures in TS-1 above.

TS-5 Selects one of the two scales of the milliammeter.

In order to accomplish these operations, selector switches are mounted on a single shaft with the pointer and index control for: Radiography—large focal spot; Radiography—small focal spot; Fluoroscopy; and Superficial Therapy. These switches are shown in Figure 64 as TS-1, TS-2, TS-3, TS-4, and TS-5. In the interest of clarity, the various elements of a single assembly operated by one lever has been separated on the diagram.

1. In the upper left of the diagram is the focal

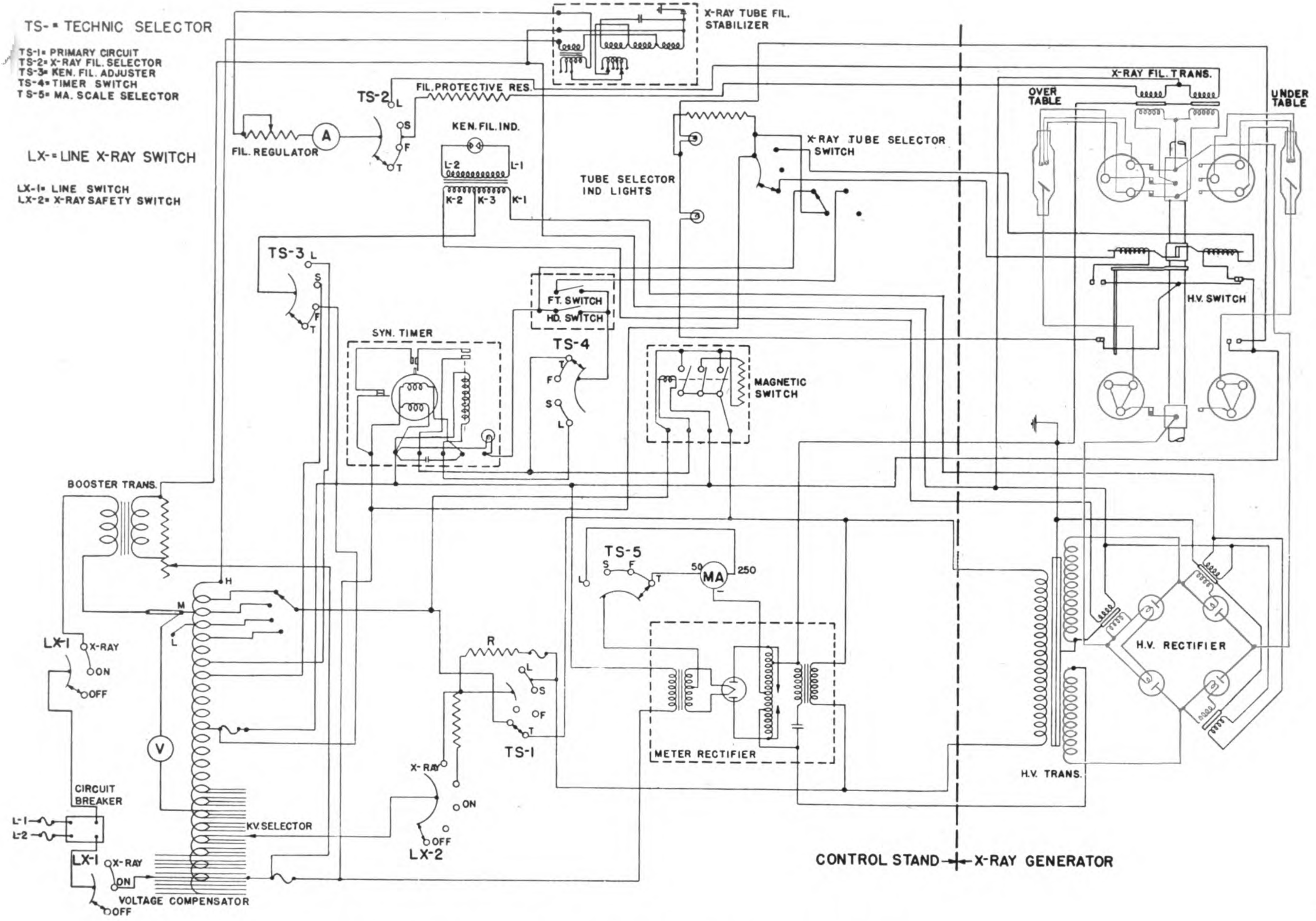

FIG. 64. Complete circuit diagram for a 200-milliampere full-wave rectified x-ray generator.

spot selector, TS-2, which energizes the primary of one of the two filament transformers connected independently to the large and small focal spots of the x-ray tube. It can be seen that if the switch is rotated so that the connecting jumper bridges the space between the inner ring and the large outer segment marked T, F, and S, the circuit is completed to the primary of the filament transformer on the upper left of the x-ray generator, the secondary of which is connected to the small filament. When the switch is rotated to the "L" position, this transformer no longer is connected to the power supply, but the primary to the right is thus energizing the large filament. The filament ammeter which indicates primary filament current is calibrated in terms of secondary amperes or tube filament current and is, of course, in the circuit for all positions of TS-2, as is the filament regulator. Note also that primary power for the filament supply is obtained from fixed taps on the autotransformer.

2. In the lower center of the diagram, Figure 64, is the milliammeter scale selector, TS-5. Its purpose is to change the scale reading of the meter and extend its range for the high current technics associated with the large focal spot. For example, if the unit is a 200-milliampere machine, the meter will have a 0-50 and a 0-200 or 0-250 milliampere scale, the latter one being selected when the technic selector is set to L (Radiography, Large Focus). Note that for T, F, S, the 0-50 milliampere scale is in circuit, since all of these procedures utilize the small focal spot as previously pointed out under TS-2 above. The milliammeter is connected to the midpoint of the high tension transformer secondary with one side at ground potential. Thus the meter can be mounted in the control panel with no danger. It will be shown in a later section that if the circuit is full-wave rectified, the current flowing through this transformer winding is alternating current, necessitating some form of meter rectifier, if a D'Arsonval type of movement is to be used.
3. For fluoroscopy and superficial therapy operation, it is desirable to insert a surge-limiting protective resistance in the primary of the high-tension transformer and to short-circuit this element for radiographic procedures on either focal spot. Technic Selector 1 performs this operation on resistance R. When the switch jumper is at S or L, it short-circuits R, whereas if it is set to F or T, the primary current passes through it.
4. In radiography, the exposure timer is operated by a hand or footswitch, thus starting the timer action. This action operates the magnetic switch designed to carry the heavy current utilized for short exposure time. In fluoroscopy, a footswitch is generally used, to operate the magnetic switch. For x-ray therapy, neither the hand nor footswitch is employed since the "ON" period is minutes rather than seconds and it is desirable to use the main line switch itself. Technic Selector 4 automatically makes the proper connections for each of these procedures corresponding to the setting on the selector indicator.
5. Technic Selector 3, left center in the diagram, is connected to different points on the autotransformer and the kenotron filament transformer primary winding so that the voltage on the latter can be increased in definite steps to match the increased current requirements for various settings of the technic selector. In this way the life of the kenotron filament is prolonged by keeping the operation at maximum temperature to the shortest time possible.

Combination Line and Safety Switch (B), Figure 62

A special switch, LX-1 and LX-2, Figure 64, lower left, combines the function of the line switch mentioned above and a safety switch. In the first of the three positions (OFF) for which the switch B is indexed, the autotransformer is completely disconnected from the power line. In the second position (ON), the x-ray tube filaments are energized together with the kenotron filaments and the timer motor. By this arrangement all preliminary settings may be made without energizing the high voltage transformer. Just prior to making the exposure, the line switch is moved to its third position (X-RAY) and the timer control may be actuated to energize the tube.

The line switch assembly consists of three switches on a single shaft with a three-setting index: OFF, ON, and X-RAY. Switch LX-1 controls the power to the input of the autotransformer. In the "OFF" position, the transformer is entirely disconnected from the supply line; in the "ON" and "X-RAY" positions, the autotransformer is energized. Switch LX-2 is the x-ray safety switch which is mounted on the same shaft but is connected on the output side of the autotransformer between it and the primary of the high tension transformer. In either the "OFF" or "ON" positions, the high voltage primary is open, as can be seen from the position of the switch shown in the diagram, Figure 64. When the line switch is moved to "X-RAY" the circuit can be completed by means of the handswitch or footswitch, *except for therapy*. The result of these interconnections is to permit setting the filament current and adjustment of all other machine factors in a "safe" position in which the x-ray tube cannot accidentally be energized. Just before making the exposure, the line switch is moved to the "X-RAY" position and the tube may then be energized.

X-Ray Tube Selector (C), Figure 62

The unit illustrated in Figure 64 utilizes two x-ray tubes, one generally used for radiography and superficial therapy above the x-ray table, while the second is mounted beneath the x-ray table for fluoroscopy and spot-film technic. The electrical connections to the tubes are made through an electro-magnetically operated high voltage switch contained in the transformer and rectifier tanks. Tube selection is accomplished by manipulation of the x-ray tube selector C, Figure 62, which on one setting connects the radiographic tube to the high voltage system and on the other setting connects the fluoroscopic tube to the high voltage system. The high voltage switch is shown in the upper right hand portion of Figure 64, while the x-ray tube selector is indicated in the upper center.

Synchronous Timer (D), Figure 62

The devices used to control the time of x-ray exposures are schematically illustrated in Figure 65. Essentially the action is as follows:

1. Closing of the hand- or footswitch by the operator completes a circuit through the timing mechanism which then starts the sequence of operation through the timer.
2. Almost instantaneously the timer energizes the magnetic switch which, in turn, starts the x-ray exposure. The need for a magnetic switch arises from the fact that the small contact in the timer itself cannot handle the heavy current involved in the high voltage transformer primary. This current may be as high as 90 amperes for a 200-milliampere full-wave rectified generator.
3. After an interval of time determined by the setting of the timer dial, the magnetic switch control circuit is opened, and the exposure is terminated.

The portion on the left in Figure 65 is a synchronous motor-operated timer designed, as its name implies, to run at a constant speed fixed by the frequency of the incoming power supply. By means of the adjustable calibrated dial, the distance between the make and break contacts may be set to any desired values corresponding to time durations of 1/20 to 20 seconds. The moving mechanism which trips the stationary make and break contacts is energized from the synchronous motor through a gear reduction system and a solenoid.

The sequence is as follows:

1. The timer motor is turned on when the line switch is in the "ON" position.
2. The indicating dial is set to the desired time value.
3. The hand- or footswitch is closed, energizing the clutch solenoid with 115 volts obtained from the autotransformer. This starts the moving mechanism completing the circuit through the magnetic switch solenoid. At the same time, the solenoid interlock closes. At the start of its travel the moving mechanism closes the make contact, completing the circuit to the operating mechanism of the magnetic switch.
4. The magnetic switch then completes the circuit to the primary of the high-tension

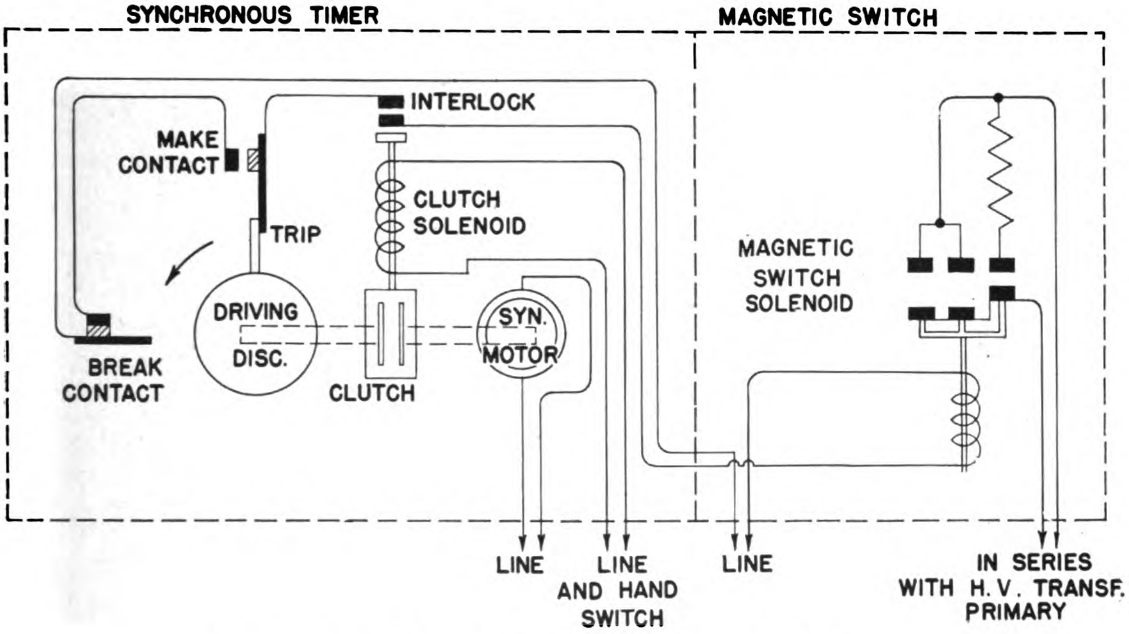

FIG. 65. Schematic diagram of synchronous timer and magnetic contactor.

transformer. It will be noted that one contact closes before the other two to insert an auxiliary resistance for a fraction of a second before full power is applied to the transformer. This prevents voltage surges due to transient currents set up at the instant of applying the primary voltage.

5. The moving mechanism of the timer continues to rotate at constant speed until it strikes the break contact and opens the circuit to the magnetic switch, which in turn opens the primary circuit to the high voltage transformer.

The synchronous timer is quite commonly employed on x-ray generators not exceeding 300 milliamperes in capacity and for exposures not shorter than 1/20 second. If maintained in adjustment, it can be expected to be accurate to plus or minus one-half cycle or 1/120 second if the frequency is 60 cycles.

Impulse Timer

For the most accurate control of short exposures (1/60 to 1/5 second), a type of timer known as an impulse timer is used. Frequently both types of timers are used conjointly, the synchronous timer for exposures longer than 1/5 second, and the impulse timer for those shorter in duration.

The essential characteristic of an impulse timer is that it starts and stops the transformer current at or very near the zero point of the alternating current cycle. This insures accuracy of timing and minimum arcing and deterioration of the make and break electrical contacts.

Circuit Breaker

It is necessary to have some automatic device for disconnecting the x-ray apparatus from the power supply in the event of failure of part of the circuit which may endanger other elements by reason of overloading. This device is known as a circuit breaker, shown in the lower left-hand corner of the diagram, Figure 64. If excessive power is drawn by the x-ray machine, a thermal element in the circuit breaker reaches a temperature sufficiently high to expand the tripping element and the power contact to automatically open. Since this is a thermal device, it requires some time for its action to take place, so that the momentary high milliampere exposures do not cause it to open the circuit despite the fact that such exposures might draw a current equal to four times the rating of the breaker. If, due to overload, the contacts are opened, it may be reset by hand, but the cause for its action should be investigated and the trouble corrected before attempting to operate the x-ray unit.

Voltage Compensators and Stabilizers

If the voltage supply to the x-ray equipment varies, it is obvious that the x-ray output and film density will change unless corrective measures are taken.

The voltage variations may be classified into three types:

1. Slow changes that occur over an appreciable period of time as, for example, over a period of 15 minutes.
2. Rapid, almost instantaneous fluctuations that are caused by the starting or stopping of some other piece of equipment on the same line as the x-ray equipment as, for example, the starting of an elevator. Of course, wherever possible, other large pieces of electrical equipment should not be connected to the same line as the x-ray equipment. Even where the lines are separate, however, there may be some influence on the x-ray line due to voltage variations at the distribution transformer or on the incoming distribution line.
3. Line voltage drop that takes place during the actual x-ray exposure and is caused by the x-ray equipment itself, that is, by the heavy current that flows during the x-ray exposure. A 200-milliampere x-ray equipment will draw approximately 70 amperes from a 220-volt line during a 200-milliampere, 80-kilovolts peak x-ray exposure. On what is considered a good power supply, this will cause a drop of approximately 6 volts, i.e., a drop from 220 to 214 volts. On a poor power supply, but one that is still considered passable, the drop may be as much as 20 volts.

The devices incorporated in an x-ray machine for dealing with the above-mentioned voltage changes usually include a voltage compensator (F), Figure 62, a booster transformer (F), Figure 63, and an x-ray tube filament transformer, Figure 64. The voltage compensator has already been described. It corrects for the slow changes of type 1 which is important in order to keep the x-ray calibration correct, and to keep a standard voltage input to all of the auxiliary elements in the control, such as the relays, solenoids, lights, and the x-ray timer motor.

Booster Transformer (F), Figure 63

The booster transformer's function is to prevent the type 3 line voltage drop that occurs during the actual x-ray exposure from causing a drop in filament current in the x-ray tube and kenotrons. It is of more importance to the kenotron filaments than it is to the x-ray filament because, in most cases, the latter also has the help of an x-ray tube filament stabilizer, which will be described on page 55.

Each kenotron filament must be operated at a high enough temperature to give off more electrons than are given off by the x-ray tube filament, making the latter the current-limiting device. Under these conditions, the voltage drop in each kenotron is relatively low, being determined by space-charge alone. If through error a kenotron filament is operated at too low a temperature (i.e., too low a filament current), it becomes the current-limiting device, its voltage drop rises to the point where it absorbs practically all of the high voltage, the x-ray output drops or becomes erratic, and the kenotron may fail due to overheating.

On the other hand, the kenotron filament must not be operated at too high a temperature or it may burn out after a short life in a manner analogous to the burn-out of an incandescent lamp that is operated on too high a line voltage. Even at correct temperature, the filament of a kenotron will eventually burn out, just as an incandescent lamp does, and it is for this reason that the filament of a kenotron should not be energized for any longer time than is necessary. Certainly it should not be left energized over night or for hours at a time unless the x-ray equipment is in constant use.

In a circuit in which there is no booster transformer, the kenotron filament current drops as soon as the x-ray exposure starts, due to type 3 line voltage drop. The filament temperature does not drop immediately because of its heat inertia, but drops gradually during the exposure. Under these conditions, in order to insure adequate temperature after this drop occurs, the filament will have to be operated at a higher current and temperature before the start of the x-ray exposure.

With a booster transformer in the circuit, the filament is supplied with an additional voltage

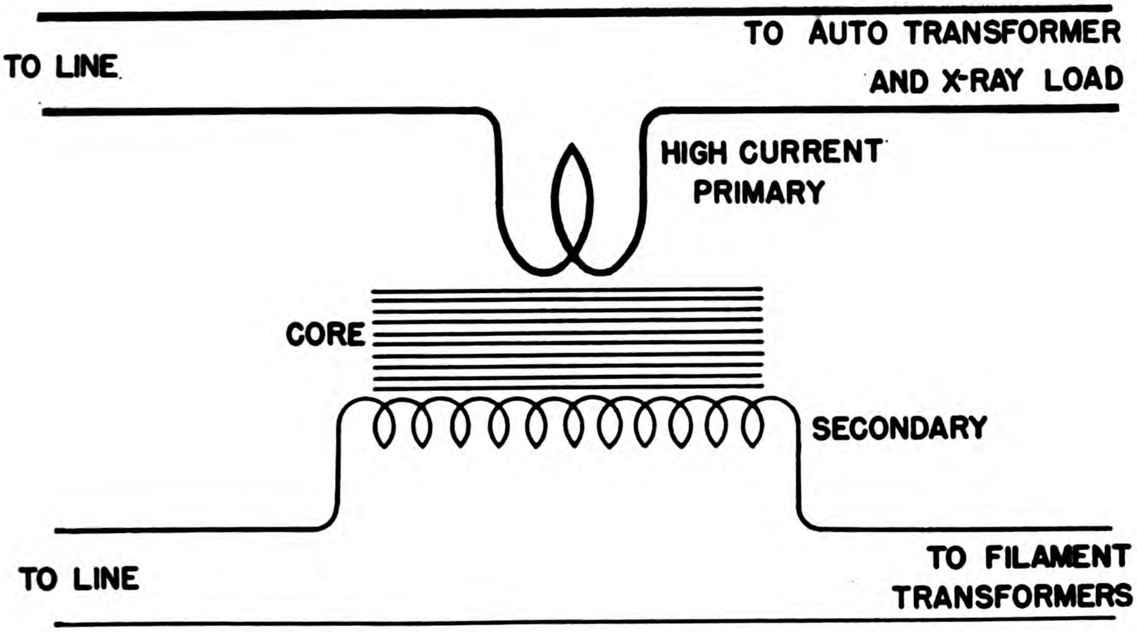

FIG. 66. Schematic diagram of a filament booster transformer.

during the x-ray exposure to compensate for the drop in line voltage that occurs. As a result of this, there is no change in filament current and the filament can be operated at a lower maximum temperature and therefore will have a longer life. Figure 66 shows the principle of operation of the booster transformer.

Its primary winding, which consists of a very few turns of heavy wire, is connected in series with the power supply so that all of the x-ray load current passes through it. The voltage drop across this winding varies with the current, but even at full load is only of the order of 1 volt. Its secondary winding consists of a large number of turns, giving a much higher voltage output than that impressed across the primary, and one which varies with the x-ray load current. This output voltage is connected in series with the filament circuit in such a way that it adds a voltage to this circuit just equal to the drop in line voltage caused by the x-ray load current.

In effect, a small amount of power is taken from a high-power x-ray load circuit and used to raise the voltage of a relatively low-power filament circuit. In actual use, a variable resistance (not illustrated) is connected across the secondary winding of the booster transformer in order to give a means of adjusting the voltage boost to that of the line voltage drop. There are no moving parts and no adjustments are required once the equipment is installed.

X-Ray Tube Filament Stabilizer

The x-ray tube filament voltage must be controlled more accurately than any other factor. The reason for this is apparent from Figure 24. It will be noted that a very slight change in filament current (and voltage) makes a great change in electrical emission, i.e., in milliamperes of tube current. Whereas the voltage compensator alone is sufficient to hold the input voltage to the x-ray high-voltage transformer to reproducible values, and the compensator plus the booster transformer is sufficient for the kenotron filaments, an additional stabilizer is desirable for the x-ray filament.

The stabilizer provides this extra stabilization. It is the only one of the three elements under discussion that eliminates the rapid line voltage fluctuations discussed under type 2. Its effectiveness is indicated by an output voltage constant to plus or minus ½ per cent with a line voltage varying plus or minus 10 per cent.

Figure 67 illustrates the principle of operation. The actual circuit employed differs slightly from that which, for the sake of clearness, is illustrated.

The stabilizer consists of two transformers

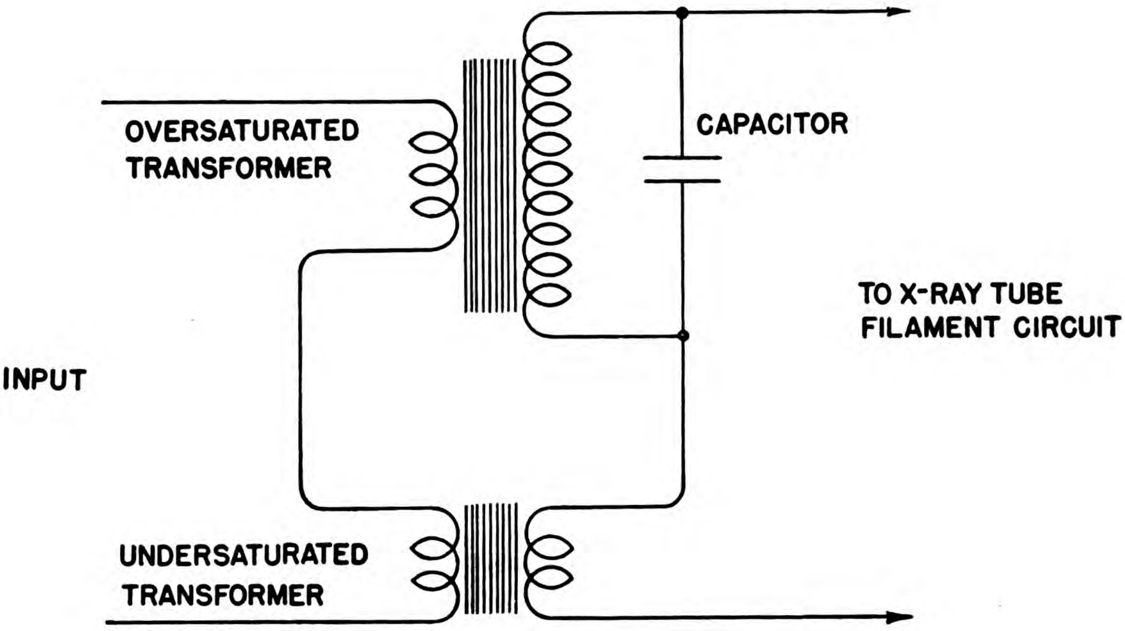

FIG. 67. Schematic diagram of a constant voltage filament stabilizer, Universal type.

with their primaries in series. The one that supplies most of the output voltage operates with a high flux density in its iron core, i.e., it is oversaturated. It is also partly resonated by means of a capacitor. The other transformer operates with a low flux density and in out-of-phase relationship to the first transformer.

When a change in line voltage occurs, the output of the saturated core transformer varies less than would be the case with an ordinary transformer. What change does occur is compensated for by a change in the "bucking" action of the output of the second transformer. There is no simple way to describe this action other than to say that by proper design the output voltages of the two transformers can be made to compensate in such a way that the total output voltage is practically constant over a considerable range of input voltages.

There are no moving parts and the stabilizer action takes place practically instantaneously. As the operation of the stabilizer depends on partial resonance, it is sensitive to frequency changes. Fortunately, most commercial power systems are kept to a constant frequency. In those cases where it does vary, as is the case with a gas engine driven generator, a stabilizer of the type described cannot be used. However, both the voltage compensator and filament booster transformer can be used, as they are relatively insensitive to frequency changes.

Kenotron Indicator (G), Figure 62

The kenotron tubes in present-day shockproof x-ray apparatus are usually immersed in oil and located in the same tank with the rest of the high voltage apparatus. Since the light given off by their filaments is not readily visible, it is seldom possible, as it was in the days before shockproofing, to determine by direct observation whether the kenotrons are lighted and in proper operating condition.

This introduces a danger because if one of the four kenotron filament circuits in a full-wave rectified apparatus becomes open-circuited, for any reason whatsoever, the rest of the apparatus may continue to operate as a half-wave rectified generator. The fact that this has occurred may not be immediately evident unless careful attention is being paid to the operating procedure. The signs of danger are:

1. A change in film density.
2. A decrease in tube current milliamperage for a given value of filament current.
3. Possible failure of the x-ray tube. This is due to the difference in allowable tube rat-

ing on full-wave and half-wave circuits as shown in Figure 29.

The kenotron indicator G, Figure 62, is intended to overcome this danger by giving a warning light in a conspicuous place on the control stand in case anything happens to the kenotron filament circuits. It consists of a neon glow lamp connected across the secondary of a small transformer, the primary of which is divided into two windings. Its operation can be analyzed from Figure 68.

The filament current supply for two of the kenotrons is passed through one winding of this primary, and the current supply for the other two kenotron filaments through the other winding. The two primary windings are wound in such a way as to induce opposing voltages in the secondary winding so that normally there is no secondary voltage to light the neon glow lamp. If the current through one of the two primary windings appreciably changes, which will occur in case of an open filament circuit, the balance of voltages will be disturbed and the neon lamp will light. The lamp lights only when there is trouble of some kind and is an indication that this trouble should be investigated and corrected before operation is resumed.

Tube Current Metering System (H), Figure 62

Under the description of a self-rectified apparatus, the milliammeter for indicating x-ray tube current was shown at ground potential connected to a center tap of the high voltage transformer (Figure 40). It is also desirable to have this arrangement with a full-wave rectified apparatus, but it is not accomplished quite as simply because in this case the transformer current is a.c. and of a different wave shape from the tube current.

Obviously a d.c. milliammeter cannot be used in the transformer. Use of an a.c. meter would introduce inaccuracies at the lower milliampere values for two reasons:

1. The scale of an a.c. meter would be crowded

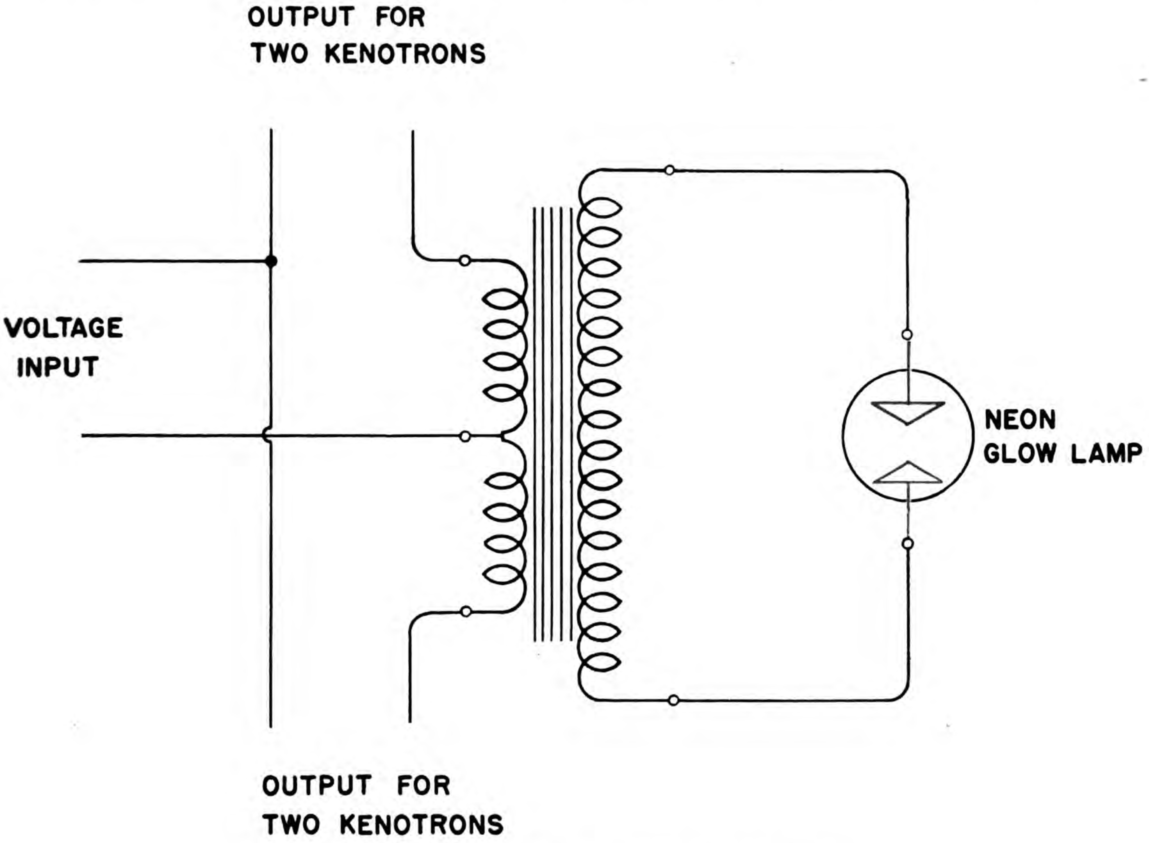

Fig. 68. Schematic diagram of a kenotron indicator circuit.

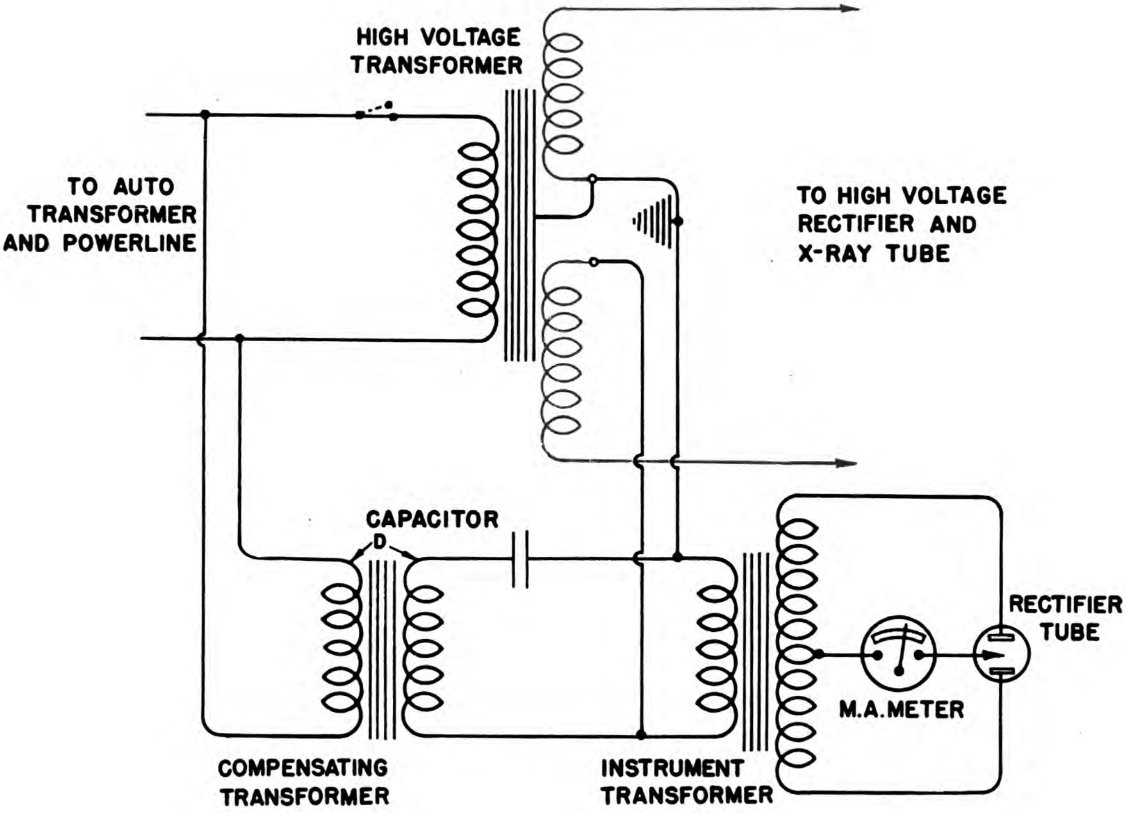

FIG. 69. Schematic diagram of a tube current metering system for a full-wave rectifier.

at its lower end. For example, there would be very little space on the meter dial between 0 and 10 milliamperes as compared to the space between 20 and 30 milliamperes. In contrast to this, the scale of a d.c. meter is much more uniform.

2. An even more serious consideration is that an a.c. meter in the transformer would read not only the x-ray tube current but also the capacity charging current to the transformer winding and high voltage cable. Because the voltages used in radiography are high—30 to 100 kilovolts peak—this capacity current has an appreciable magnitude, being of the order of several milliamperes. It is a variable, depending upon the kilovoltage and the length of shockproof cable.

The metering system of Figure 69 is designed to overcome the difficulties just enumerated.

The high voltage transformer current is rectified by means of the instrument transformer and rectifier tube, so that the d.c. milliammeter H can be used, and the advantages of its more uniform scale obtained. The compensating transformer in conjunction with the capacitor applies a current to the instrument transformer just equal and opposite in direction to the capacity charging current of the high voltage system. The capacity current is, therefore, balanced out and no longer read by the meter. Note that the primary winding of transformer D is connected across the primary of the high voltage transformer, and, as the kilovoltage and capacity current increase, the balanced current also increases. Taps on D allow compensation at the time of installation for different lengths of high voltage cable. Although this may seem like a great deal of complication in order to read tube current, it is necessary for accuracy, and it has proven to be a very reliable metering system.

Semi-Automatic Control

Despite the increased complexity in the circuits and construction of modern x-ray apparatus, its control and operation is less complex and more reliable than older types. Figure 70 is an illustration of a semi-automatic control for a generator similar to that described in the preceding pages. The technic selector of Figure 64 has been modified to select directly the desired tube milliamperage by automatic filament current adjustment. The autotransformer selector switch is coördinated through a mechanical interlock to indicate kilovolts peak directly for a number of selected milliampere values through the range of the transformer. By these controls, kilovolts peak and tube current can be pre-set without need for reference to calibration charts or filament characteristic curves or data. For accuracy and x-ray tube protection, some method must be provided for automatic space-charge compensation. In the unit shown, this is done by directly interlocking the autotransformer control with the primary of the filament circuit of the x-ray tube. In addition, the gradual change in emission characteristics of the tube as it is used must be suitably compensated. This is done by periodic adjustment of a master filament control.

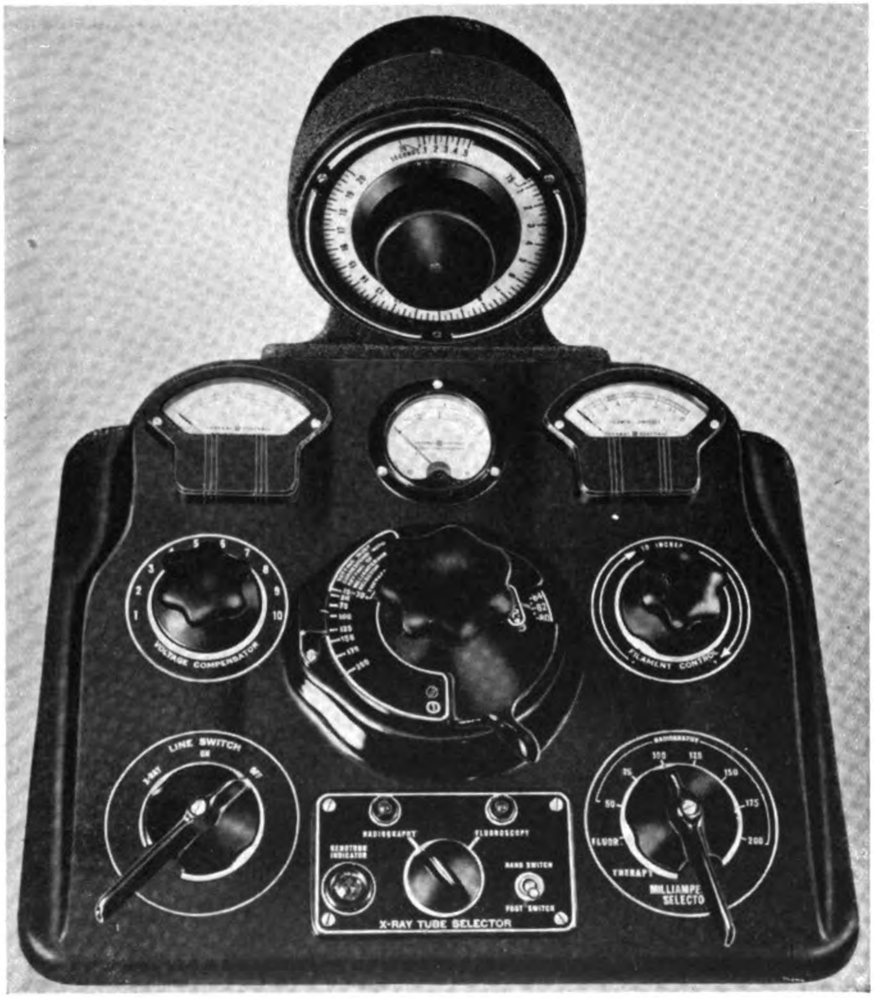

FIG. 70. Semi-automatic control, 200-milliampere generator.

Figure 71 is an illustration of a semi-automatic control for a 500 milliampere generator. This is an even more advanced centralization of control devices, including a fluorographic unit, two timers, and a Potter-Bucky diaphragm interlock indicator, etc.

Other Rectifying Circuits

The full-wave 4-kenotron bridge circuit just described is used in the great majority of high-power x-ray apparatus having a capacity of 200

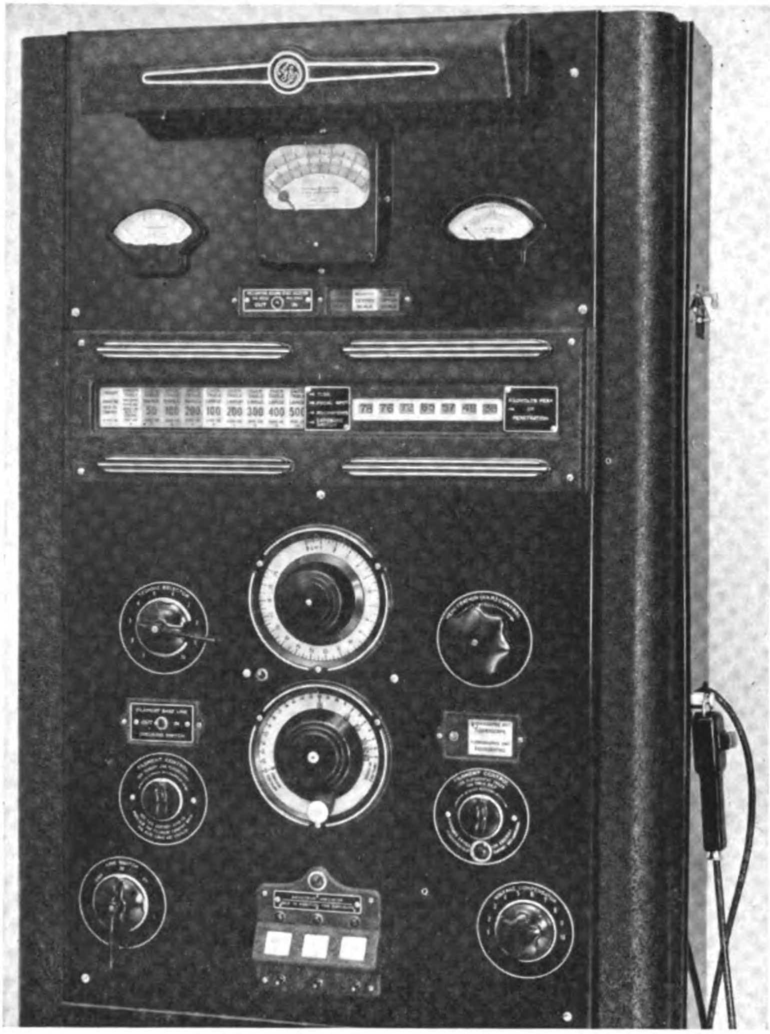

FIG. 71. Semi-automatic control, 500-milliampere generator.

milliamperes or more. Medium and low-power equipments (100 milliamperes or less) are usually self-rectified. There are other high voltage rectified circuits employing different combinations of kenotrons and transformers, but none is used to the extent of the 4-kenotron circuit. This, over a period of years, has proven to have, more than any of the others, the desirable qualities of reliability, reasonable cost, and high allowable tube rating. The other circuits occasionally used in radiography include the half-wave rectifying circuit, the three-phase rectifying circuit, and the capacitor-discharge circuit.

Three-Phase Rectification

Figure 72 shows the essential elements of a three-phase 6-kenotron rectifier. Although this is a rather complicated circuit, its general principles of operation are not difficult to understand.

Each of the three high voltage transformers, Nos. 1, 2, and 3, Figure 72, generates a voltage 120 degrees out of phase with respect to the other transformers, which in non-technical terms means that the a.c. voltages of the three transformers do not rise and fall simultaneously, but rather successively in fixed relationship to each other, as shown in Figure 73. The rectifying circuit is so arranged that it supplies a voltage to the x-ray tube at each instant approximately equal to the sum of the two highest of the three transformer voltages. The x-ray tube voltage (and current) is always greater than zero, being supplied first by one and then by another combination of the transformers.

The operation of the circuit is best understood by considering what happens at different instants of time, and for each instant tracing the path of electron flow. The arrows on Figure 72 represent electron current flow at an instant of time when transformers 2 and 3 are supplying the useful voltage and current to the x-ray tube. The voltage of transformer 1 at this instant is either zero or close to zero, and this transformer is inactive, that is, it is not supplying any of the current to the x-ray tube. One-twelfth of a cycle later (1/720 second) the voltage of transformer 1 will have increased to the point where it is slightly greater than that of transformer 2, which has been decreasing. The current which has been flowing in transformer 2 will start to shift to transformer 1.

One of the fundamental properties of electricity is that current flow in a circuit cannot be stopped or started instantaneously. This inertia

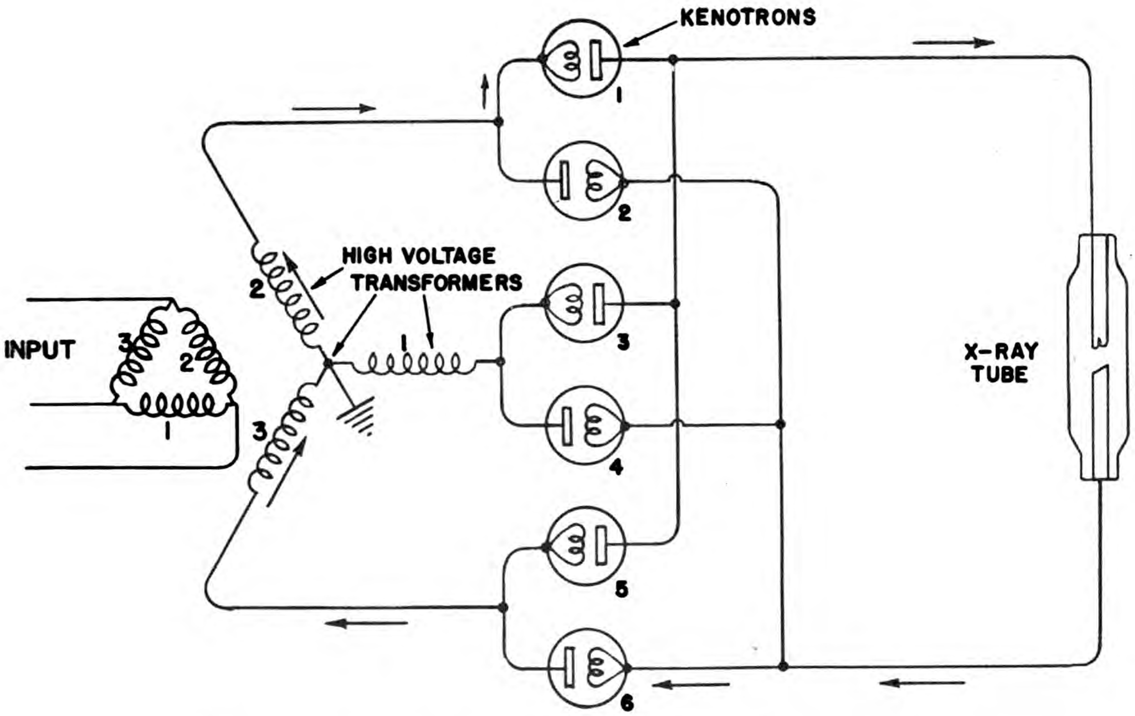

FIG. 72. Schematic diagram of a three-phase, six-kenotron, high-voltage generator.

effect, analogous to the inertia of physical bodies, is very important, and is a function of the inductance of the circuit. In a high-voltage transformer, it has an appreciable magnitude and is related to a characteristic of the transformer known as leakage reactance. Consequently the current in transformer 2 takes a significant length of time to die out and the current in transformer 1 a significant length of time to rise to its full value. There is a transition period when current is flowing in both, illustrated by the arrows in Figure 74. During this period the voltage supplied to the x-ray tube drops, as shown by A in Figure 73 and Figure 75.

After the transition is completed, current flows for a short time in transformers 3 and 1, Figure 76. In 3/12 of a cycle, however, the voltage of transformer 2 has reversed in direction and in-

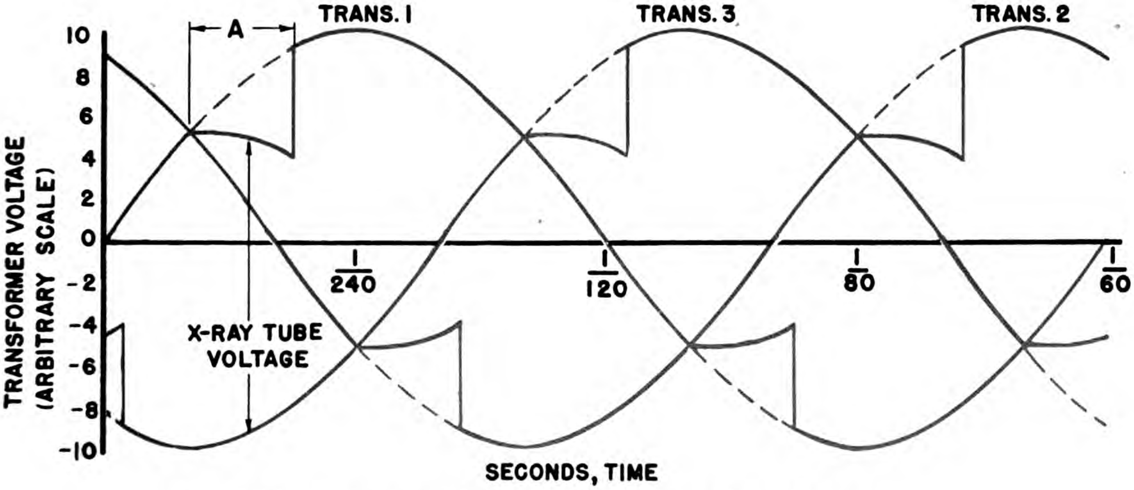

FIG. 73. Time-voltage curves for the three transformers of a three-phase rectifier.

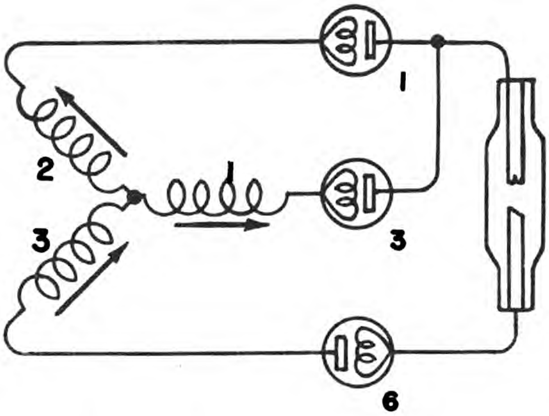

FIG. 74. Direction of electron flow.

creased to the point where it is slightly greater than that of transformer 3. As a consequence, the current in transformer 3 starts to shift to transformer 2. Another transition period is gone through, after which the current is flowing only in transformers 2 and 1. The electron current can be traced in this manner through four more transitions from transformer to transformer until it returns 1 cycle later (1/60 second) to the condition under which the analysis started.

The resulting x-ray tube voltage wave shape is shown in Figure 75. Note that the voltage never drops to zero, but that it varies in a complicated manner over an appreciable range. The magnitude of the change from maximum to minimum voltage cannot be stated exactly because it is a function of many variables, including the transformer leakage reactance and the tube current. In most cases it will have a magnitude of variation of the order of 20 to 40 per cent of the maximum voltage. In practice, the wave shape is even more irregular than that illustrated as the theoretical shape.

Figure 77 shows the commonly accepted tube voltage wave shape for a three-phase generator. This is obviously incorrect and misleading.

Figure 78 is a spinning-top radiograph taken on a three-phase generator operating at 500 milliamperes, 58 kilovolts peak, and 1/20 second. Note that the film density varies cyclically over a wide range, as is predicted from Figure 75.

Figure 79 is a spinning-top radiograph taken on a single-phase generator operating at 500 milliamperes and 1/20 second. Note that the actual differences in density are not much different from those of Figure 78, though there are fewer impulses, as is expected.

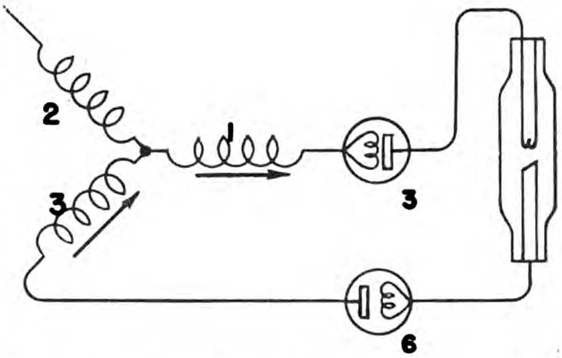

FIG. 76. Direction of electron flow after transition of flow from transformer 2 to 1 is complete.

There is considerable confusion as to the relative merits of single- and three-phase rectification.

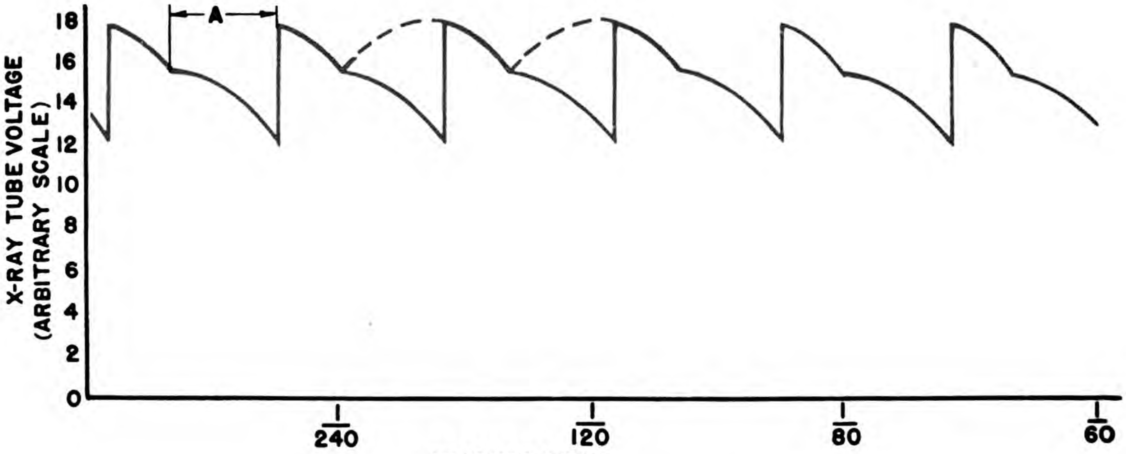

FIG. 75. Resultant x-ray tube voltage wave shape.

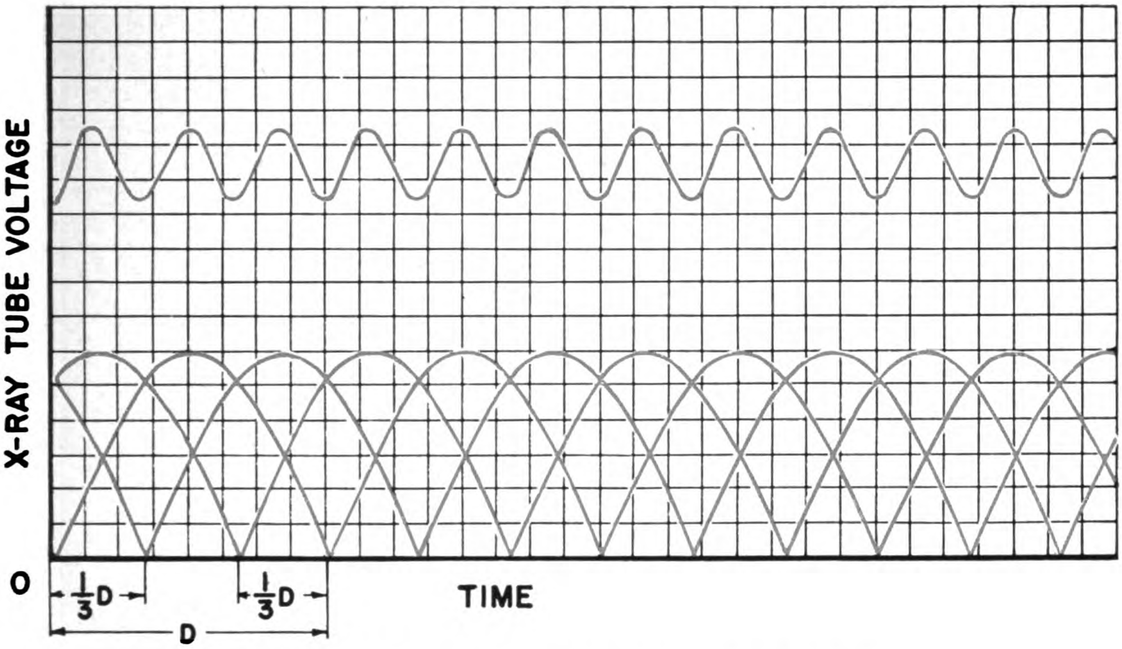

FIG. 77. Commonly accepted representation of tube voltage wave shape

Some of this has been caused by accounts of three-phase rectification in the literature which completely ignore the transition and inertia phenomena emphasized in the preceding paragraphs. When this is done, the erroneous conclusion is reached that the output voltage across the x-ray tube varies only 14 per cent, which is much less than that shown in Figure 75. If this were the case, it would not be difficult to believe, as is often accepted as a fact, that the three-phase circuit gives an appreciably greater x-ray output and consequent greater radiographic speed.

Actually repeated experiments by a number of independent persons indicate little or no difference in radiographic speed between three-phase and single-phase rectified equipment operating

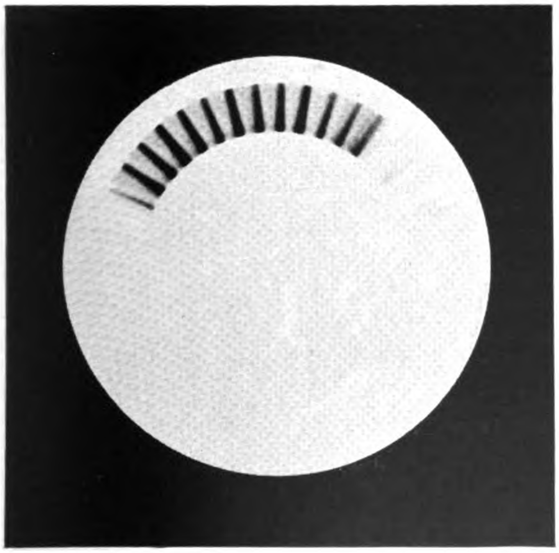

FIG. 78. Spinning-top radiograph on a three-phase generator.

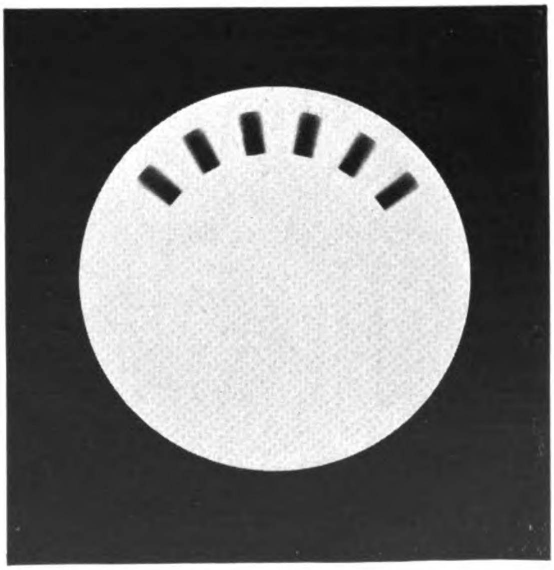

FIG. 79. Spinning-top radiograph on a single-phase generator, 1/20 second.

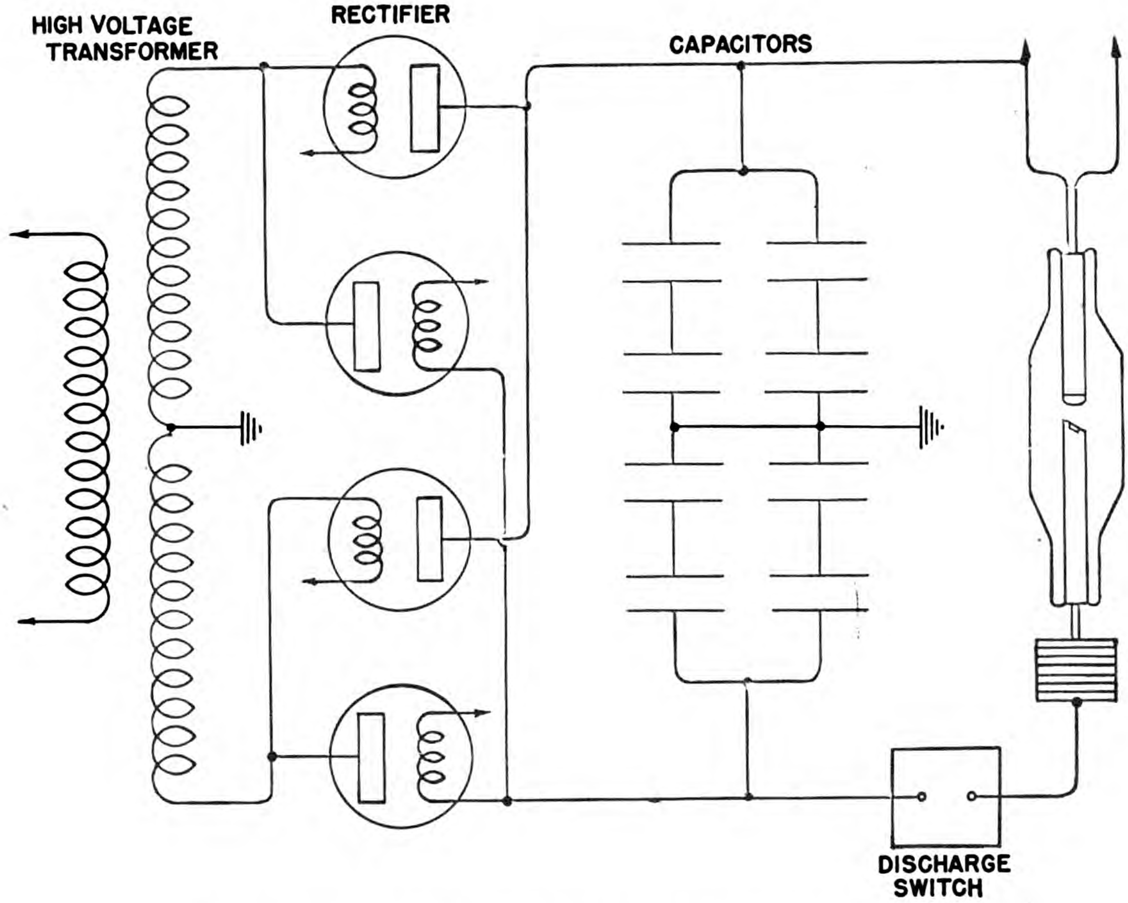

FIG. 80. Schematic diagram of a capacitor-discharge x-ray generating apparatus.

at the same kilovolts peak and milliamperage. It is true that for short exposures (1/20 second or less) x-ray tubes will stand about 15 to 20 per cent more energy on three-phase. Even this slight gain is likely to be lost, however, because of the difficulty of timing high energy short-time exposures on three-phase without introducing erratic behavior, as for example, in the inaccuracy noted in Figure 78, which should show 18 dots and actually gives 13. In timing, there are three primary circuits to be closed and opened, and the current is never 0 in all three of them at the same time. On long x-ray exposures (1 second or more) the x-ray tube will not stand as much energy as it will on single-phase full-wave rectified voltage.

Capacitor Discharge Apparatus

A type of power supply which has had certain specialized applications is the condenser discharge unit. Its operation is based on the fact that a capacitor is essentially a reservoir for electricity which can be charged relatively slowly to a given potential by a direct current source of electricity, and can then be made to discharge rapidly through an x-ray tube, giving up all its contained energy in a single impulse. The objective in the use of this principle is to attain short exposure times with power supply of limited capacity. This has only been partially realized because of limitations which will be discussed on page 66.

The charge stored in a capacitor is given by the equation:

$$Q = CV$$

in which Q = charge in coulombs
C = capacity in farads
V = potential in volts.

This can be rewritten as milliampere-seconds = microfarads times kilovolts peak.

Thus, a 1 microfarad capacitor charged to a potential of 60 kilovolts peak will deliver on discharge 60 milliampere-seconds.

Figure 80 is a schematic diagram of a capacitor-discharge unit. The condenser is charged by power obtained from a generator which may be a conventional 4-kenotron full-wave apparatus. The charging operation is performed by simply energizing the transformer. During the charging period, a time dependent upon the power output of the rectifier, the discharge switch is in the open position, isolating the x-ray tube from the remainder of the circuit. After the capacitor is fully charged, the exposure is made by closing a hand switch which actuates the solenoid controlling the discharge switch.

The x-ray tube may be thought of as a resistance whose value depends on the number of electrons available for the conduction of current from cathode to anode. If the electron emission as determined by the filament temperature is high, the effective resistance of the tube is comparatively small, and the discharge of energy in the condenser takes place very rapidly, 1/50 second, for example. If the filament current is low, the effective resistance of the tube is high, and the discharge time is comparatively long, as for example, 1 second. In both cases the total amount of energy discharged through the tube is the same. This circuit is unique in that there is no timing element to control the length of the exposure, this being determined by the capacity, the voltage, and filament current as indicated above.

As with other types of generators, the permissible rate of discharge is limited by the temperature of the focal area of the x-ray tube employed. For a rotating-anode tube with a focal spot of 1 mm^2 (projected) the values in Figure 81 are the maximum permissible ratings when operated from a 1 microfarad capacitor.

Useful Discharge Time	*KV P*	*Peak MA*
1/10 Second	70	450
1/15 Second	64	600
1/20 Second	58	725
1/30 Second	48	800

FIG. 81. Energy rating for a rotating-anode tube operating from a condenser discharge apparatus, capacity 1 microfarad.

The useful discharge time given in Figure 81 is that portion of the total discharge time which is effective in producing roentgenographic density.

Figure 82 is a reproduction of an oscillographic record of tube voltage and current for a unit employing a 1 microfarad capacitor in which the filament temperature is high enough to produce a very rapid discharge. In this case the total discharge time is 1/120 second. If the filament temperature is decreased appreciably, an oscillogram of the form shown in Figure 83 results. The same total energy is given off by the capacitor in both cases, but the time in which the discharge takes place is quite different.

Capacitor discharge apparatus is a specialized type which has had a limited application in chest radiography. It has been used in attempts to operate from power supplies of limited capacity. In stereoscopic radiography this is not possible

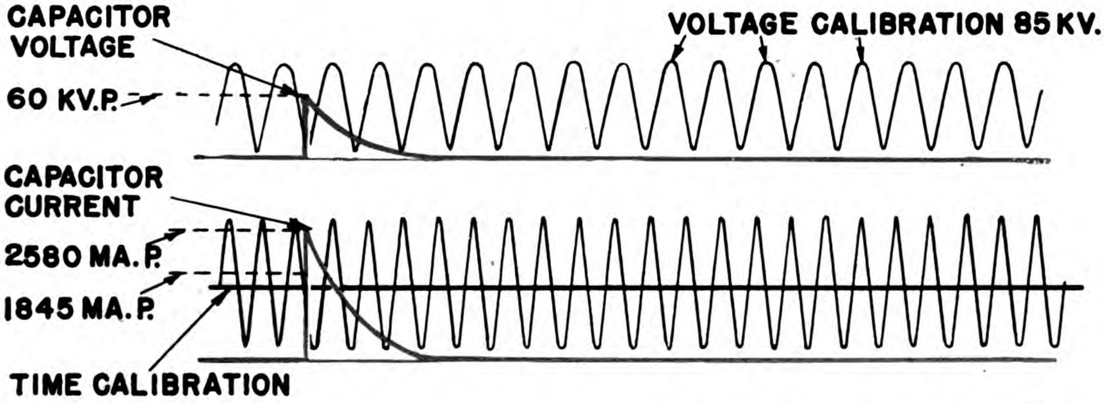

FIG 82. Oscillographic record of tube voltage and current, 1 microfarad capacitor, high filament temperature.

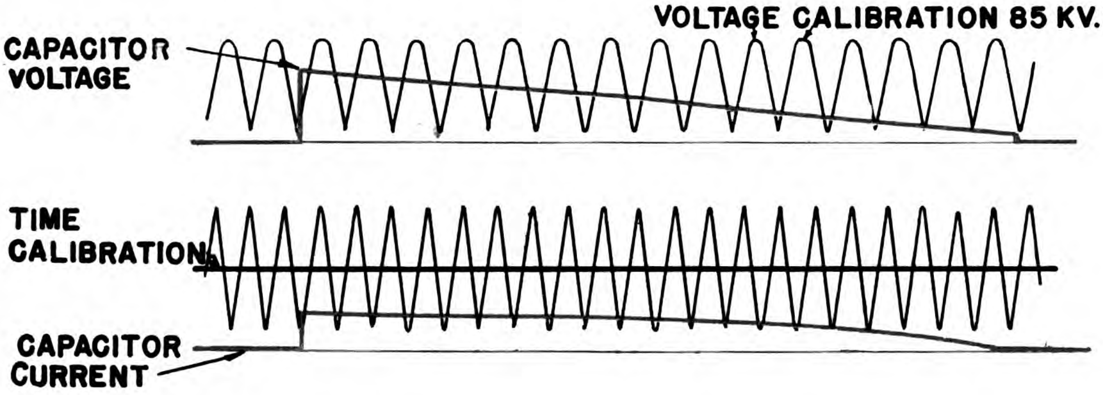

FIG. 83. Oscillographic record of tube voltage and current with decreased filament temperature.

because two exposures in rapid succession are required. The charging apparatus must then be sufficiently powerful to charge the capacitor in a fraction of a second thus obviating the advantage of the reservoir action of the discharge principle.

Since milliampere-seconds cannot be controlled independently of kilovolts peak, flexibility in technic is another disadvantage, one which is only partially overcome by providing a selection of capacitor values in the equipment. For example, if the condenser is of 1 microfarad capacity, the quantity of electricity stored in it when fully charged is 60 milliampere-seconds at 60 kilovolts peak; for ½ microfarad, 30 milliampere-seconds at 60 kilovolts peak. This quantity is completely discharged through the x-ray tube when the exposure is made and it cannot be regulated except as to the time in which the discharge takes place as previously described.

Because of difficulty in stereoscopy, limited flexibility in selection of radiographic technic, and appreciably greater cost compared with conventional equipment, condenser discharge apparatus has not found extensive use.

Radiographic Calibration

THE DEVELOPMENT of any science brings with it not only an increase in utility and a broadening field of application, but a growing need for more perfect tools by those engaged in the practice of that science. As an individual increases his proficiency, he becomes more aware of technical problems.

X-ray technicians have become more proficient year by year, recognizing these technical problems. This chapter is devoted to one of those problems which means a great deal in the production of a better end result. This is the problem of calibrating energizing equipment in such a way that a milliampere-second procedure may be employed over the entire efficient range of the available equipment.

Experience has shown that kilovolts peak, as measured with the sphere gap, multiplied by milliampere-seconds (milliamperes multiplied by time), cannot successfully be used as a measurement of quality and quantity of x-ray energy emanating from the x-ray tube. This has been known for a great many years, but it has been only in the past few years that a means has been found whereby the x-ray beam may be calibrated in terms of quality and quantity of x-ray energy over the entire *efficient* range of the energizing equipment. *The word "efficient" is used because there are many instances wherein an energizing equipment may be rated at, for example, 500 milliamperes, yet have a radiographic efficiency rating of only 250 to 300 milliamperes, and such an equipment may be successfully calibrated only up to these milliampere values.*

This method of calibration is referred to as radiographic calibration. When an energizing equipment has been properly calibrated radiographically, the user may greatly increase the flexibility of his equipment because then he will be able to predict the end result even though wide variations may be made in milliamperage from a baseline procedure.

This method provides a means for utilizing a milliampere-second technic rather than a set procedure made up of milliampere and time values, thus stabilizing a given quality per kilovolts peak, regardless of the milliamperage, providing the time is changed to maintain the original milliampere-second value.

For example, suppose that the procedure employed for an extremity is 20 milliamperes, 5 seconds, 40-inch distance, and 50 kilovolts peak. The milliampere-second value is 100. Because of *the danger of motion* it is desired to reduce the time to one second without changing the quality of the end result. If the equipment has been radiographically calibrated, 100 milliamperes at 50 kilovolts peak, or 100 milliampere-seconds, is used. This applies over the entire efficient range of the energizing equipment.

A milliampere-second procedure cannot be used unless the quality and quantity of x-ray energy per kilovolts peak-milliampere-seconds over the efficient range of the equipment is constant. There can be no doubt that the best radiographic result requires variable procedures for the same part. Modern transformer and control design should make this possible in such a way that the results are predictable without the necessity for testing or guessing, as the case may be.

It is impractical in most instances for the technician to completely calibrate his equipment radiographically because essentially this is a manufacturing laboratory procedure. However later in this chapter (see page 69) a procedure will be given which may be used by the technician as an approximate radiographic check on x-ray generator performance.

Complete radiographic calibration of any x-ray generator requires the utmost care if the most useful results are to be obtained. Bear in mind that the finished calibration chart of kilovolts peak and milliamperes, whether incorporated as a part of the equipment or in separate chart form, must be based on both quantity and quality of x-ray energy. Thus it is essential that the milliampere value be correct to plus or minus 3 per cent, and the time factor may be sufficiently accurate so that it will not affect the film density. For this reason an impulse timer is employed for the timing of all exposures shorter than 2 seconds. Most impulse timers have a range of 1/60 or 1/120 second to 1/5 second. Thus, for a 2-second exposure, ten 1/5-second exposures are made. For exposures over 2 seconds, a modern synchronous timer is ordinarily quite accurate and dependable.

The first step is to establish a baseline of kilovolts peak and milliamperes. This baseline calibration is at a low milliampere value, 10 to 50, depending on the range of the energizing unit. A 100-milliampere unit, for example, would have a baseline of 10 or 20 milliamperes. A 200-milliampere unit, 20 to 30 milliamperes. A 500-milliampere unit, 20 to 50 milliamperes.

At these milliampere values, accurate sphere gap readings can be made. At the low milliampere values mentioned, it is quite practical to accurately determine sphere gap voltages as the milliammeter may be read and altered, if necessary, as the spheres are brought together due to the length of time the tube may be safely energized. The resulting kilovolts peak values are carefully corrected for atmospheric conditions.

After the baseline milliamperage has been chosen, eight points of calibration are taken between 30 kilovolts peak and 100 kilovolts peak; that is, 10 kilovolts peak apart. If the autotransformer indicates button numbers rather than kilovolts peak, the autotransformer setting is changed until the desired kilovolts peak is measured with the sphere gap, to plus or minus 1 kilovolt peak, and charted on a graph. See Figure 84, which represents only the baseline.

If the autotransformer buttons read directly in kilovolts peak, these values are disregarded and referred to merely as buttons. For example, suppose that the sphere gap, operating under proper conditions, reads 45 kilovolts peak. If the kilo-

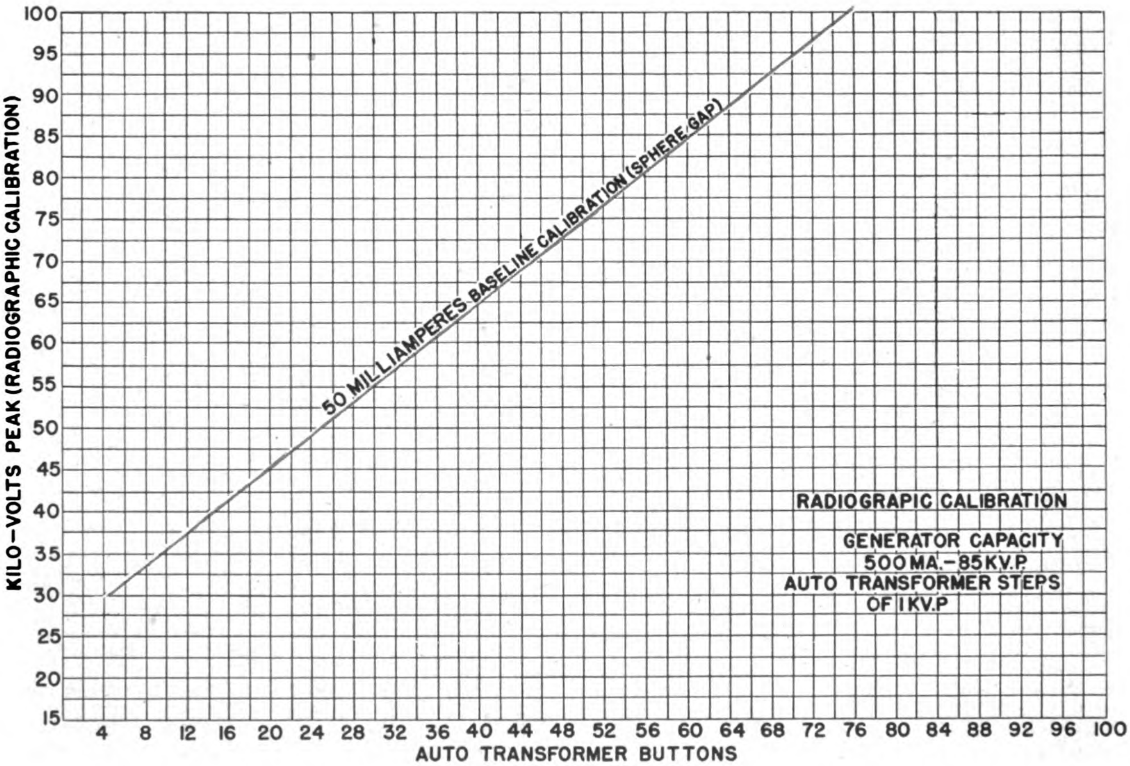

FIG. 84. 50-milliampere baseline calibration (sphere-gap). The calibration at this value can generally be taken from the chart furnished with the apparatus.

volts peak dial reads 52, then it is obvious that a correction must be made. Manufacturers have various ways of doing this, one being by shifting the kilovolts peak dial.

It is from the sphere gap calibration (baseline) at low milliamperage that all other kilovolts peak-milliampere values are determined radiographically. There is no doubt that under certain conditions and with some types of equipment, it is possible that the low milliampere values may not represent the highest x-ray output per kilovolts peak-milliampere-seconds due to wave distortion. Experience indicates, however, that this is rare and in general the low milliampere values are the most favorable to check with the sphere gap from this standpoint. It is at the medium and high milliampere values that difficulties may occur.

As previously discussed, the baseline is now complete, and radiographic calibration begins.

The subject used is an aluminum penetrometer or ladder having 11 steps. The first is 5 millimeters and each succeeding step 3 millimeters additional, step 11 having a thickness of 35 millimeters. The width is just under 3½ inches so that four views of the penetrometer can be made on one 14 by 17 film lengthwise.

Radiographic calibration, when properly done, necessitates the use of intensifying screens, usually the Parspeed type. *It is only by using intensifying screens that small differences in density are visible.* The latitude without screens is such that wide variations in kilovolts peak and/or milliampere-seconds might occur without sufficient visible difference. This also applies to any particularly slow intensifying screen.

The following is the actual procedure in radiographic calibration. The example in this instance is an energizing unit having a rated capacity of 500 milliamperes at 85 kilovolts peak. The baseline, made as previously described is at 50 milliamperes as in the graph, Figure 84.

The first milliampere value above 50 to be radiographically calibrated is 100 milliamperes. The penetrometer is placed to one side of the film or cassette, Figure 85, and the balance of the film protected with lead. *Each exposure on each film must be carefully marked.* The focal-film distance must be sufficiently great so that danger of anode cutoff is eliminated. Usually 60 inches or 72 inches are employed. This greater distance also serves another purpose in that at the higher voltage and milliampere values the proper density will be obtained without resorting to impractical exposure time values.

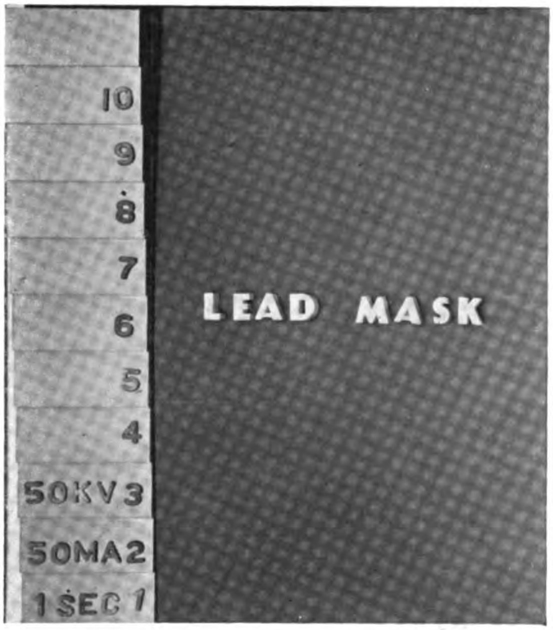

FIG. 85. Position of penetrometer on film for calibration exposure.

Inasmuch as the example given is a 500-milliampere generator, it is necessary to use a rotating-anode tube in order to carry the maximum values.

The autotransformer is adjusted for 30 kilovolts peak at 50 milliamperes as shown on the baseline calibration. A number of 500-milliampere generators cannot be operated as low as 30 kilovolts peak at 50 milliamperes, in which case the starting point should be the lowest kilovolts peak value obtainable.

Regardless of how the penetrometer is made up as regards thickness of the various steps, a sufficient number of milliampere-seconds should be employed to show at least the two bottom steps at the lowest kilovolts peak value. As each succeeding exposure is made with increased kilovolts peak values, more and more steps will show. The number is not particularly important except at the very low voltage, in which case a minimum of two steps should be visible.

The actual problem. The first exposure, taken from the baseline, is made with the penetrometer positioned as in Figure 85. There are three spaces left on the cassette for subsequent exposures. The penetrometer is moved to the second space, the first as well as the last two being covered with lead, and the first 100-milliampere exposure is made in the same number of milliampere-seconds as exposure No. 1. In this case, whatever time of exposure was used at 50 milliamperes is reduced to one-half at 100 milliamperes, and a higher autotransformer button must be used. It may be only one or two, but whatever the number is, the objective is to find the autotransformer button at 100 milliamperes, which will produce a density that will duplicate the calibration exposure. The three exposures at 100 milliamperes should be made approximately one button apart on the average equipment.

Following processing of the film, it will be found that one of the 100-milliampere exposures either matches the 50-milliampere calibration exposure or at least is nearer to it than the other two. *It must be kept in mind that in matching penetrometer films all of the steps which have been shown on the baseline exposure must be matched by one of the three exposures made at 100 milliamperes.* It is well to mention here that this applies for the entire calibration at all milliampere values.

When the proper autotransformer setting has been found, it is plotted on the graph or chart as 30 kilovolts peak at 100 milliamperes.

The next calibration point is 40 kilovolts peak, and the same procedure is followed. In other words, the first exposure is at 50 milliamperes and the 40 kilovolts peak value is taken from the baseline. Following this the autotransformer button is found which at 500 milliamperes will duplicate the baseline film or exposure on all visible steps of the penetrometer. Upon completion of the 100-milliampere calibration, it is customary to calibrate at 200, 300, 400, and 500 milliamperes.

Figure 86 is a completed calibration of a 500-milliampere equipment as done in the fac-

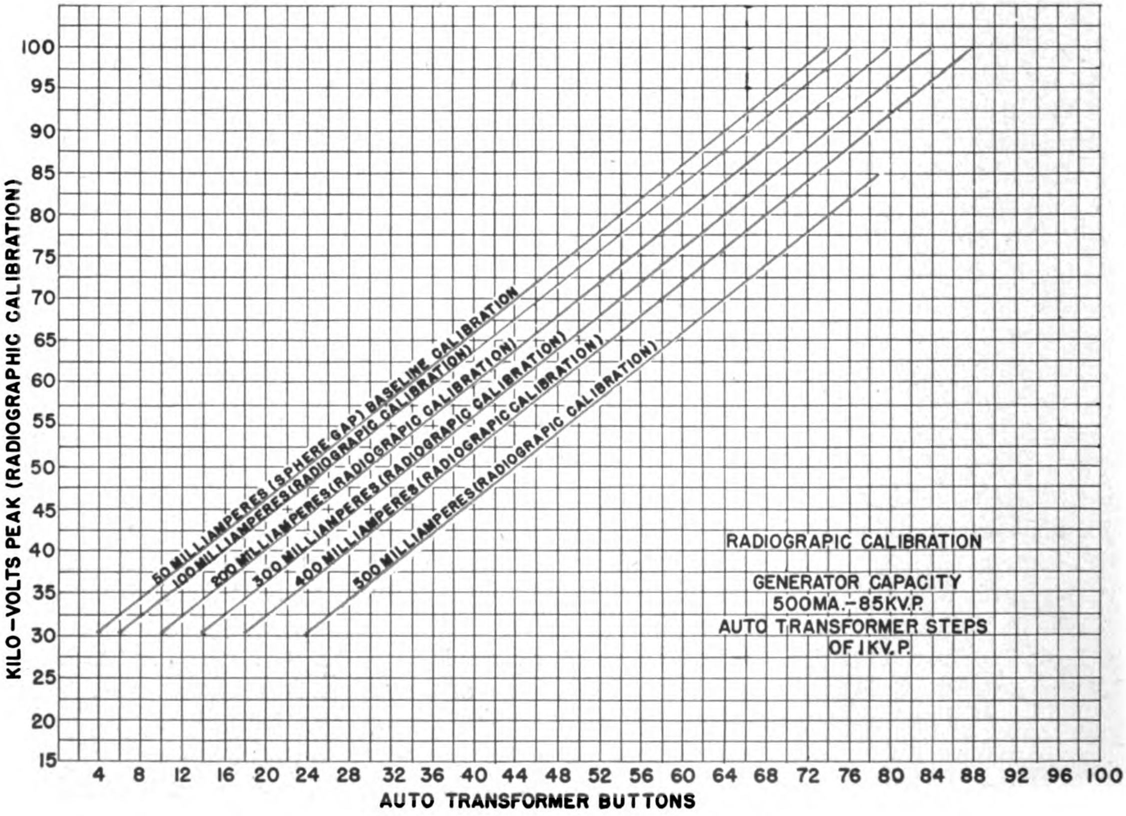

FIG. 86. Completed radiographic calibration of 500-milliampere unit.

tory by the manufacturer. Oftentimes if a calibration is done in the field, the technician may not desire as many values as shown in Figure 86; particularly is this true with older types of apparatus.

It should be seen from the foregoing description of radiographic calibration that if an equipment can be, and is calibrated radiographically, it places the operator in a position whereby many technical procedures are made available. If the standard procedure for an antero-posterior lumbar spine is 100 milliampere-seconds, 40-inch distance, 60 kilovolts peak, it makes no difference as to how the milliampere and time factors are changed so long as the limit of the tube is not exceeded. Whether it be 100 milliamperes for 1 second, 200 milliamperes for ½ second, 400 milliamperes for ¼ second, or 500 milliamperes for ⅕ second, the quantity and quality of x-radiation is constant.

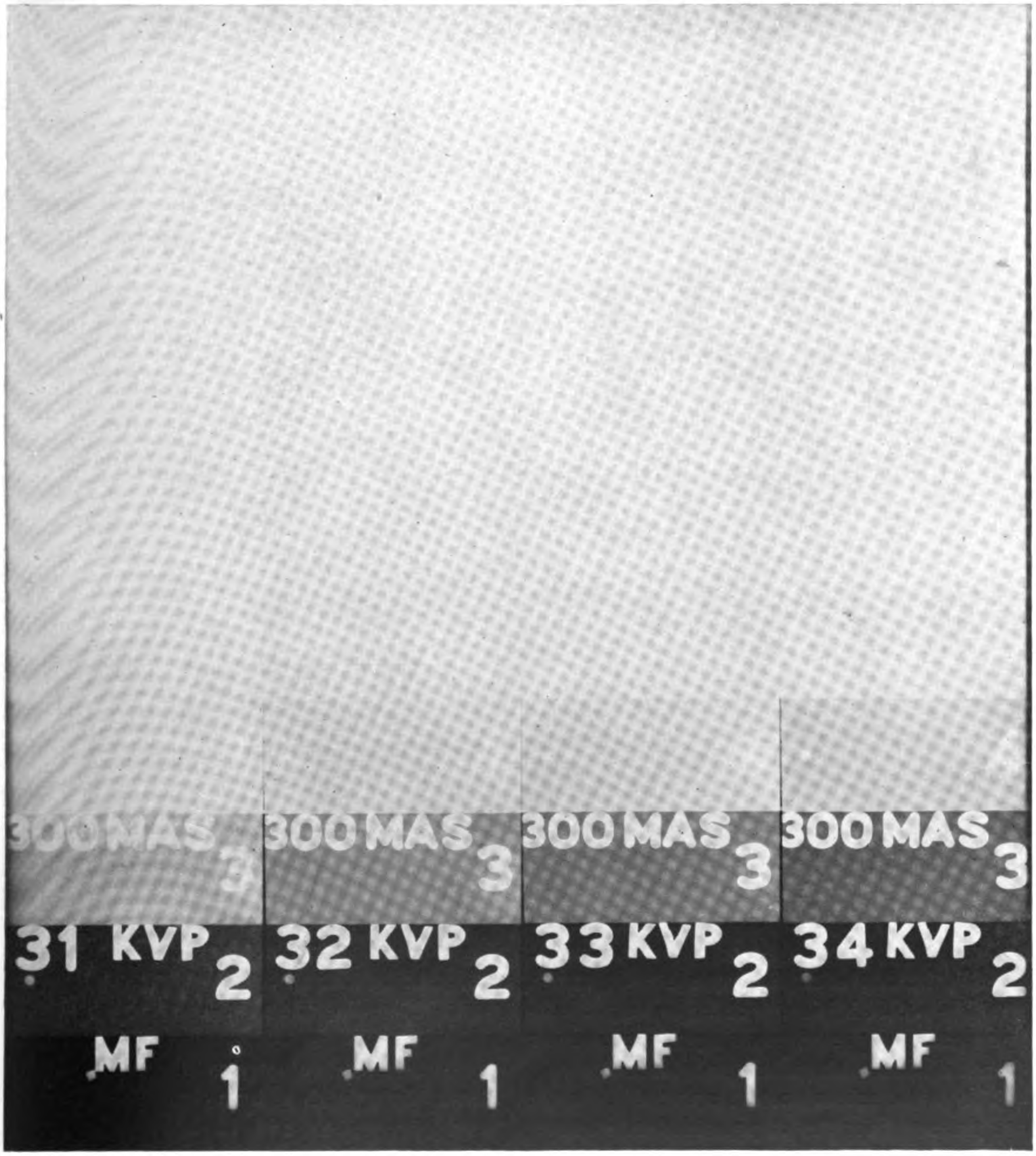

FIG. 87. Change in density produced by change of 1 kilovolt peak at values between 30 and 40 kilovolts peak.

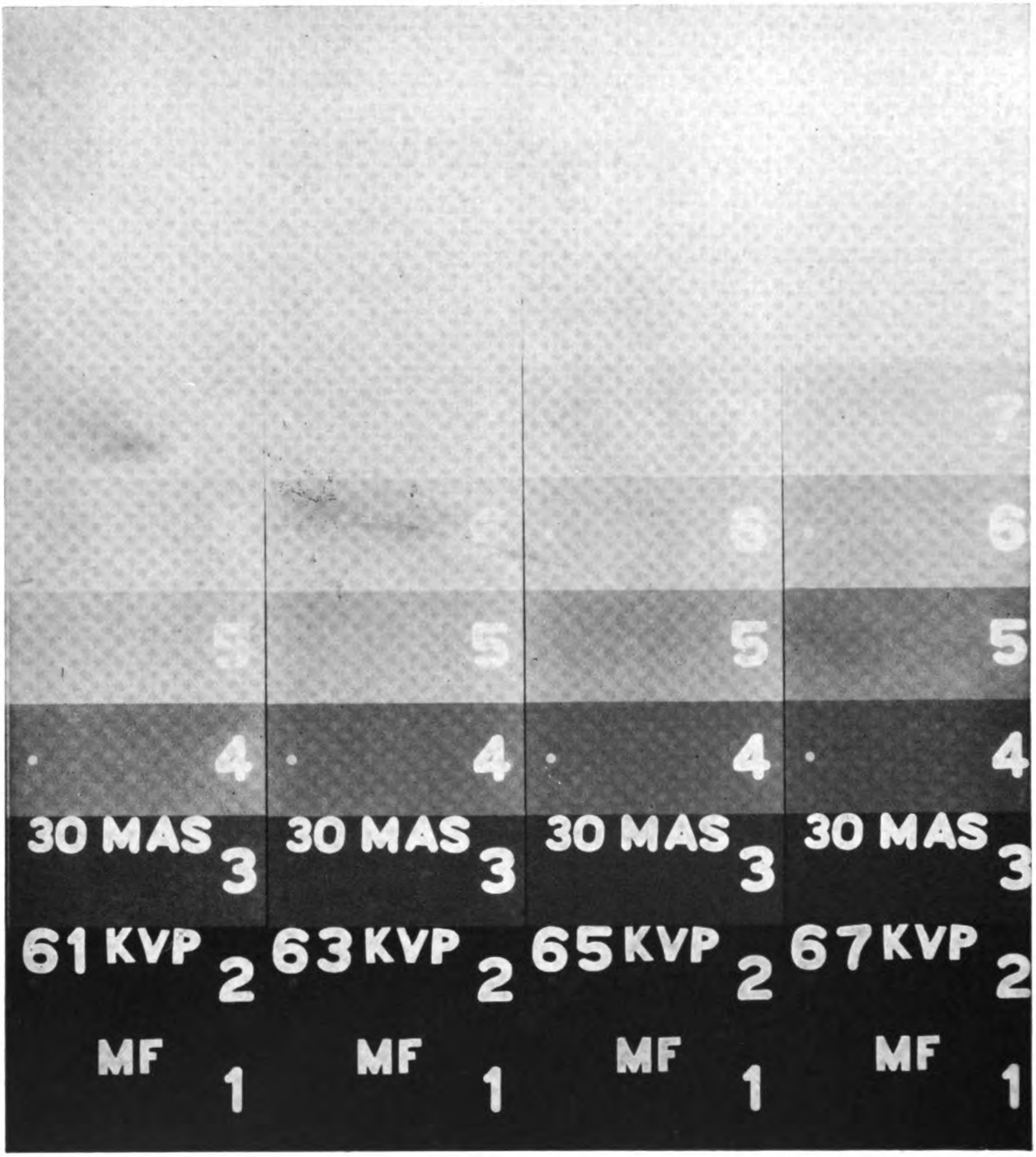

FIG. 88. Change in density produced by change of 2 kilovolts peak at values between 60 and 70 kilovolts peak.

Changes visible when using the penetrometer for calibration are very much more noticeable than in the case of regular routine radiography. In other words, it is much easier to see a 2 kilovolts peak change when using a penetrometer than it is when taking a lumbar spine radiograph.

The reproductions accompanying this chapter are presented for the purpose of demonstrating the general appearance of various penetrometer exposures.

Figure 87 demonstrates the difference in density brought about by a change of 1 kilovolt peak at values between 30 and 40 kilovolts peak. The differences in density are plainly visible.

Figure 88 demonstrates the difference in density brought about by a change of 2 kilovolts peak between 60 and 70 kilovolts peak. At these voltages it requires a change of 2 kilovolts peak to make a noticeable change in density.

Figure 89 demonstrates the difference in density brought about by a change of 3 kilovolts peak at values between 70 and 80 kilovolts peak. At these voltages it requires a change of 3 kilovolts peak to make a noticeable change in density.

Figure 90 is an example of radiographic calibration. In this instance it will be noted that the baseline calibration is 10 milliamperes. The baseline exposure is 10 milliamperes, 55 kilovolts peak, as taken from a baseline calibration using 25 milliampere-seconds. As mentioned previously, the second, third, and fourth exposures represent the radiographically calibrated values at 500 milliamperes. Each of these three penetrometer exposures was taken at 25 milliampere-seconds, the same as the baseline exposure but at 500 milliamperes. Careful inspection of these penetrometer exposures will show that exposure No. 3 more nearly matches the calibration ex-

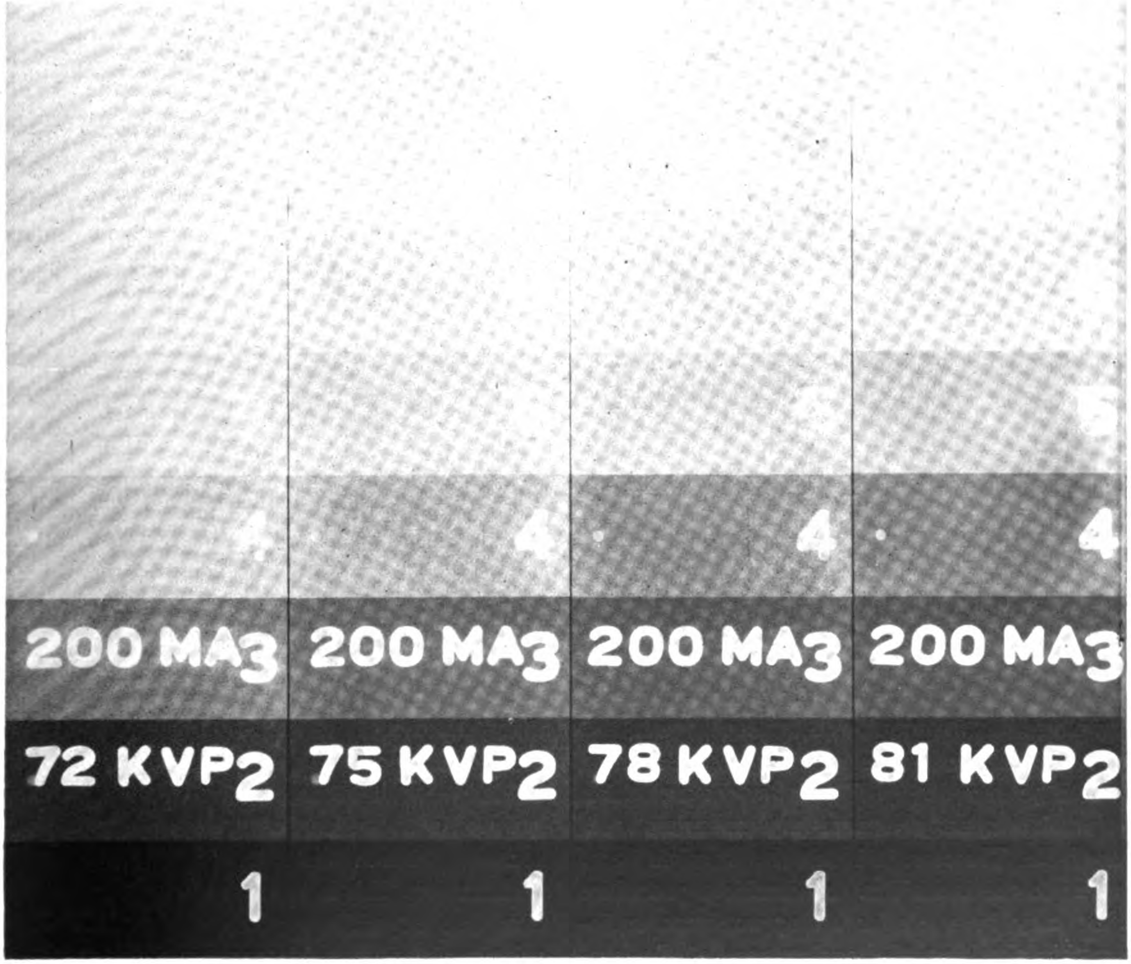

FIG. 89. Change in density produced by change of 3 kilovolts peak at values between 70 and 80 kilovolts peak.

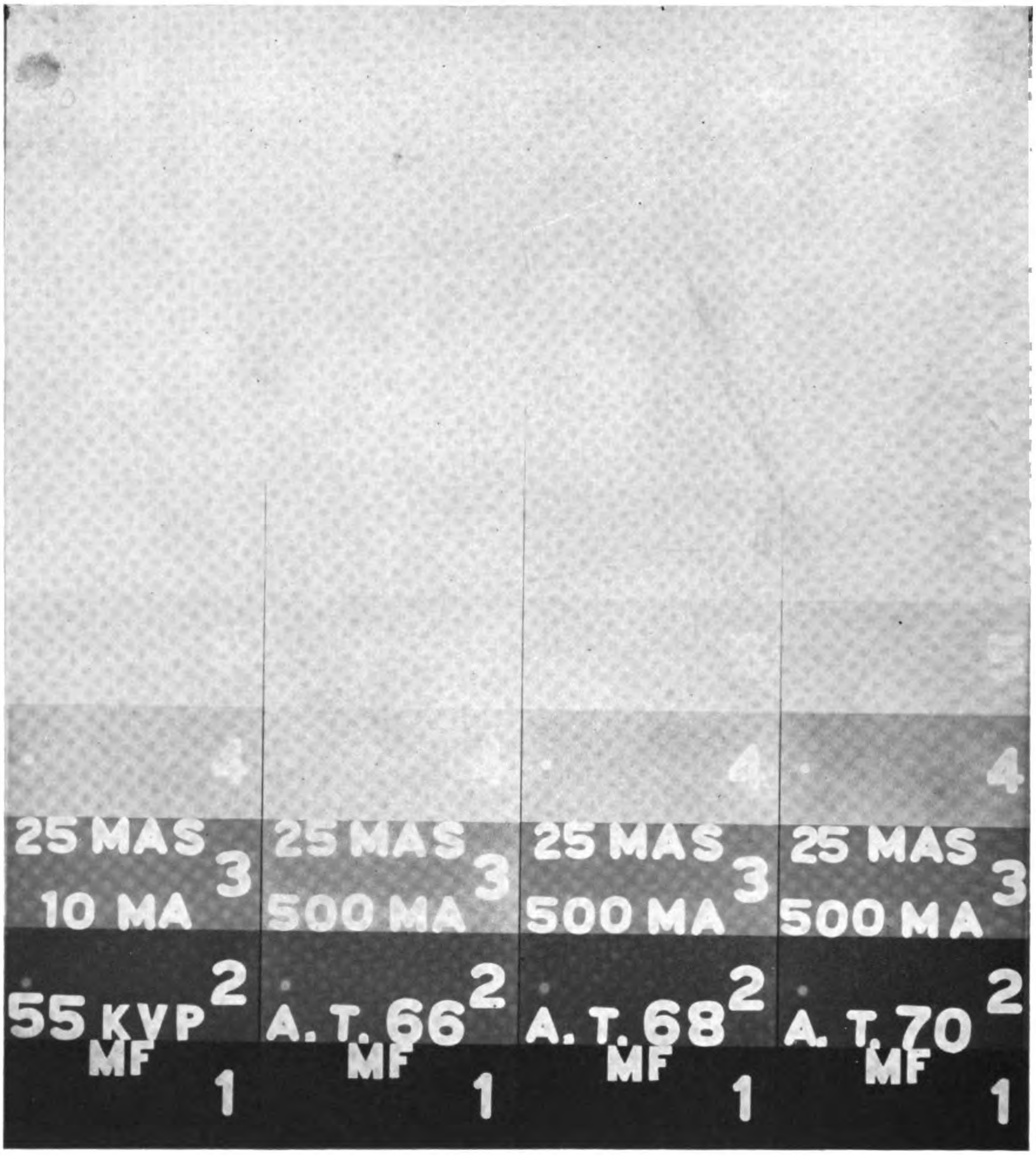

FIG. 90. Example of radiographic calibration, baseline at 10 milliamperes.

posure. Thus, autotransformer button 68 should be plotted on the graph as 55 kilovolts peak.

A full and complete radiographic calibration would be exceedingly difficult for the technician to make unless the necessary materials were available. Therefore it is felt that it might be of value to the technician to describe a procedure that may be used for an approximate radiographic check on the performance of the generator installed.

Instead of using a penetrometer made of aluminum, the next best type of penetrometer is a human chest. If the generator capacity is 100 milliamperes, it is recommended that two radiographs be taken, one using 10 milliamperes, 2 seconds, 72-inch distance, 55 kilovolts peak, with screens. This is, of course, with the assumption that 20 milliampere-seconds and 55 kilovolts peak will provide a useful density at 72 inches. Following this on the same patient, use

100 milliamperes, 1/5-second, or 20 milliampere-seconds, and 55 kilovolts peak.

Theoretically these two films should be approximately of the same technical quality, even though motion would probably be visible in the 2-second exposure.

If the equipment has a capacity of 200 milliamperes, follow the above procedure, but use 1/10 second at 200 milliamperes, instead of 1/5 second at 100 milliamperes. The lower milliampere chests should be taken with the factors given above.

If the equipment has a rating of 500 milliamperes, and an impulse timer and rotating-anode tube are available, the low milliampere chest should be taken at 50 milliamperes, 1/2 second, 72 inch distance, at the kilovolts peak given above, namely, 55. The high milliampere chest should be taken at 500 milliamperes, 1/20 second, using the same kilovolts peak value.

There will be some difference between each pair of films. It would not be at all unlikely if one film were slightly darker than the other by perhaps 2 or even 3 kilovolts peak. However, if it is found, for example, that the 50-milliampere chest on the 500-milliampere unit is somewhat near correct, and the 500-milliampere chest is virtually a blank, then it should be evident that it would be entirely impractical to use a milliampere-second procedure over the entire range of the apparatus. This may be caused by a poor power supply not recognized at the time of installation of the apparatus, or it may be a change in wave form as between the two technical procedures. The manufacturer's representatives should have little or no difficulty in finding where the trouble lies.

Finally, the value of radiographic calibration and of equipment specifically designed to utilize it is mainly to the user of the apparatus. It is becoming increasingly evident that the technic of the future will require highly variable procedures. In order, however, that variable procedures be utilized with a degree of simplicity necessary to make their use widespread, there is a definite means for the actual expression of the output of the x-ray generator in terms of the ultimate effect upon the film to be used for diagnosis. Radiographic calibration is just such an expression. *With equipment so calibrated, it becomes possible to use a complete milliampere-second procedure over its entire useful range.*

The technician is then not confined to any set technic but has available a multiplicity of procedures which makes possible a better end result based upon the individual and particular area, and not upon an unsound basis of attempting to use a specific technic for a given part of the body regardless of the existing pathology or the many other factors which enter into the production of radiographs of the highest diagnostic quality.

Factors Affecting the Quality of the Radiograph

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PRESENT DAY knowledge of radiography has proceeded from an accumulation of facts derived intuitively, unrelated, disorganized, and little understood. A number of interested and inquiring persons have for many years, by the application of logical reasoning and experimental investigation, progressed from the trial and error method of procedure to an orderly system of correlating the many physical factors and laws which are interrelated.

In the field of operative x-ray technic the foremost problem is that of determining a means whereby the utmost tissue differentiation may be shown radiographically in any part of the body.

To produce a radiograph of any part or area that will make possible the visualization of all the structures simultaneously, and so plainly visible that they may be readily identified, is the ideal. Any technical procedure must obviously be based upon those factors which can be successfully utilized and controlled with the equipment and tube available. The operator must thoroughly understand the manipulation of the various factors necessary to consistent duplication of high quality radiographs, and further, if application of the principles involved is carried to the limit of the capability of the equipment, the result will be of the highest quality.

What is a radiograph? It is a permanent record of the variation in x-ray opacity brought about by proportionate differences in x-ray absorption of the respective tissues. Were it not for the fact that the various structures within the human body varied in opacity, radiography would be impossible. On the other hand, if there were a very definite difference in opacity or absorption between each and every type of tissue and under all conditions, radiography would indeed be very much simplified. Or, if the human body were made up in such a manner that tissues adjacent to each other varied considerably in opacity or x-ray absorption, many of the difficulties in surmounting the problem of maximum tissue differentiation would be obviated.

In those areas within the body wherein a considerable variation in opacity does exist, a multiplicity of technical procedures will produce excellent results. On the other hand, as this difference in opacity is reduced between one part and another immediately adjacent to it, or because of intervening tissues, the operator is confined to a relatively narrow range in operative procedure if maximum differentiation of tissue is to be obtained.

In a satisfactory radiograph, structures will be visible to the extent that they are differentiated from their surroundings due to differences in opacity or contrast.

After recognizing a particular part by virtue of its tissue differentiation, it is natural to look for detail sharpness. The lines of structure may be sharp or diffuse, one of the characteristics which establishes the quality of the film. Most of the factors which control this quality, as will be seen later, are mechanical or geometrical.

Maximum differentiation of tissue is realized only when the film shows both maximum sharpness of detail and maximum visibility of detail.

It is not intended that the following material shall go into the fullest detail regarding each of the factors presented. The purpose is to present these factors in the form of general considerations and to so segregate them that a better understanding of the prime essentials, sharpness of detail and visibility of detail, is obtained.

I. Detail Sharpness or Definition

A. Size of Tube Focal Spot

The focal area of an x-ray tube is the area of electron bombardment on the target or, more generally, that portion of the anode which intercepts the electron stream. Since x-rays are generated as a result of this bombardment, the focal area can further be described as the region from which the rays diverge as they proceed from the tube. The terms "focus" and "focal spot," often loosely used as synonyms, have attained general acceptance by common understanding. It is important to recognize that the x-ray beam is emitted not from a point, but from *a definite area,* rectangular in modern radiographic tubes, the actual dimensions of which range from 1 millimeter (the width of the smallest) to approximately 5 millimeters (the width of the largest). To cover this range, there is a selection of standard sizes available, in single and double focus combinations.

The underlying reason for the development of higher powered apparatus was to overcome the difficulties in diagnostic value which have resulted from loss of detail due to motion. There was a demand for and a need for a reduction in exposure time to diminish the effect of motion on detail sharpness of the various parts of the body. In tracing this development, it is found that in many cases the time of exposure has been reduced from a matter of seconds to a small fraction of a second.

The use of high power x-ray apparatus with a resultant decrease in time required for radiography of those regions subject to motion brought with it one disturbing complication which limited full realization of the improvement in definition, or detail sharpness. X-ray tube energy rating must be increased to safely handle the increased power. Since most of the energy dissipation for short-time exposures takes place in the focal area, this must be made progressively larger with the capacity of the radiographic equipment. The table, Figure 91, shows a relationship between size of focal spots and tube ratings. The dimensions given are the size of a square projection at 90 degrees to the tube axis in the plane of the long dimension of the incident electron beam. *The ratings supplied are for full-wave rectified equipment.* It is seen from these fragmentary ratings that the energy limitations bear a definite relation to size of focal area. With properly designed generating apparatus, the x-ray output should be proportional to the tube current (milliamperes) and so the circle is completed. With more powerful tubes and equipment, the exposure values are reduced and the effect of motion is diminished.

Focal Spot Size	*Tube Rating at 70 Kilovolts Peak, 1/10 Second*
1.5 millimeters	38 milliamperes
2.0 millimeters	80 milliamperes
2.7 millimeters	125 milliamperes
3.8 millimeters	200 milliamperes
4.5 millimeters	275 milliamperes
5.1 millimeters	325 milliamperes
1.0 millimeters (rotating)	200 milliamperes
2.0 millimeters (rotating)	500 milliamperes

FIG. 91. Relationship between size of focal area and maximum permissible tube current at 70 kilovolts peak, 1/10 second, full-wave rectifier.

Figure 92 illustrates the projection of a line between the end points P_1 and P_2 removed some distance from the film surface. It may represent a line of structure within the body resting on

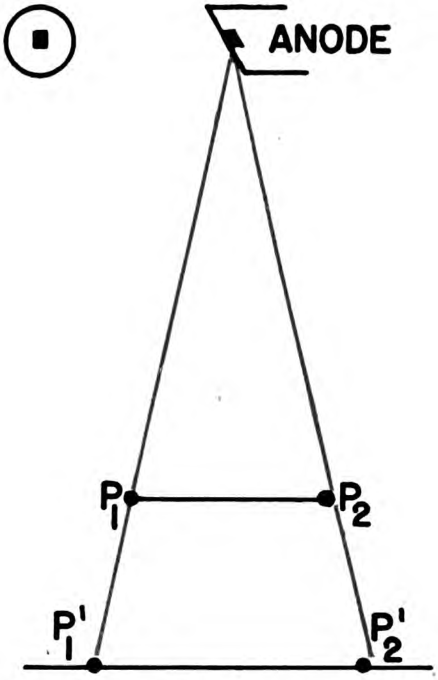

FIG. 92. Diagram illustrating projection of points with an x-ray source of small area.

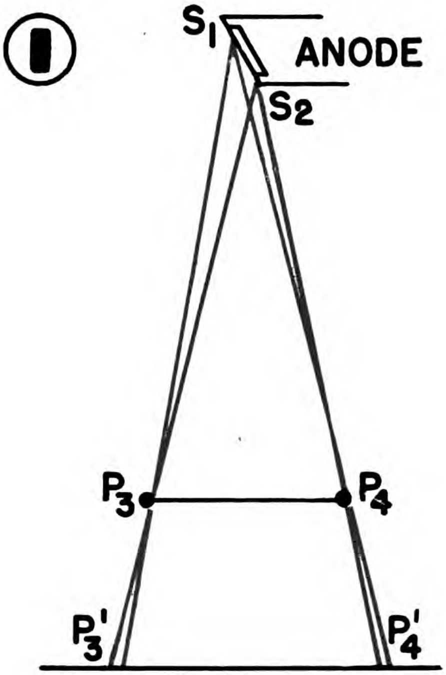

FIG. 93. Diagram illustrating projection of points with an x-ray source of large area.

an x-ray table top. The shadows of the end points are cast as shown as P_1' and P_2' respectively, intercepting rays from an infinitely small source, the theoretical but never realized focus. In this illustration, Figure 92, the sharpness of the original structure is preserved because points are projected on to the film as points.

Figure 93 shows the effect of a focal area of definite proportions as it is met in varying degrees in actual practice. The points P_3 and P_4 intercept radiation from the entire area, delineated by its limits S_1 and S_2. The projections P_3' and P_4' are no longer sharp points. They become blurred areas, their definition established by the disparity of S_1 and S_2 on the target. If the focal area is small, then S_1 and S_2 are close together and the degree of blurring of projected points is lessened. If the focal area is increased, S_1 and S_2 are spaced farther apart and the degree of blurring is emphasized.

Therefore, larger focal areas, made necessary by the increase in capacity of energizing apparatus may destroy the very improvement in detail sharpness which the shorter exposure values should produce. Fortunately, the blurring produced by the larger focal areas does not entirely cancel the improvement brought about by reduction in motion. If this were not so, there would be no reason for equipment of higher power. *If motion were not a factor,* the use of low-power apparatus could be extended over the entire range of radiography.

Figure 94 is a radiograph of a lateral lumbar spine taken with a 4.5 millimeter focal spot. Figure 95 is a comparison of the same area on the same patient using a 1 millimeter focal spot, both radiographs having been taken at a distance of 40 inches. The detail sharpness as obtained with the smaller focal spot represents a substantial improvement.

Thus far the following conclusions can be reached regarding the effect of the size of x-ray tube focal spots on sharpness of detail, and the technical limitations which limit the realization of maximum sharpness of detail in radiographs of all parts of the body when using stationary anode tubes.

1. The development of the science of radiography has been in the direction of reducing exposure time to diminish the effect of motion of the various areas of the body.
2. The introduction of high power apparatus

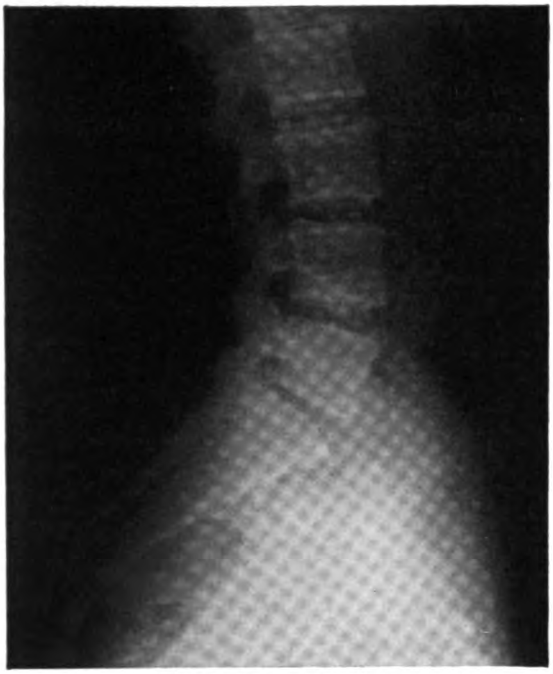

FIG. 94. Radiograph of lumbar spine, 4.5 millimeter focal spot.

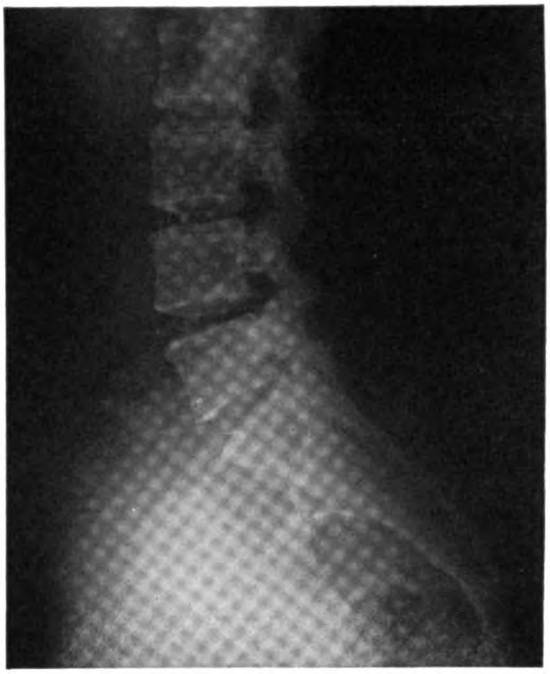

FIG. 95. Radiograph of lumbar spine, 1 millimeter focal spot.

to accomplish this reduction in time of exposure.

3. The necessity for x-ray tubes with increased focal areas in order to adequately take care of the greatly increased power.
4. Limitation of desirable detail sharpness by geometric blurring resulting from large focal spots, but a certain net gain in the combined use of high power equipment, and x-ray tubes with large focal spots over low power equipment with small focal spots.

B. The Rotating-Anode Tube

With the resultant energy becoming greater and the size of the effective focal spot becoming larger, it can be well seen that a vicious circle was rapidly developing. At this point a practical means to the desired end was found. Note that the statement as made refers to a practical means because a theoretical means has been known for some time. A number of years ago Dr. Elihu Thompson of the General Electric Company developed an x-ray tube having a rotating target. Basically it involves moving the target area of electron bombardment with respect to the electron beam so that for the entire duration of the exposure the area under impact is constantly changing. With the utilization of the rotating target tube, there resulted a greatly increased energy rating in comparison to that of the stationary anode tube, having the same focal spot size. Since most of the energy dissipation for short-time exposures takes place over the focal area, it is evident that the greatly increased area must result in a greatly increased capacity. The theory of the rotating-anode tube is described in Chapter II.

Thus, by combining the possibilities of short-time exposures to reduce the effect of motion with small focal spots which require no sacrifice of the advantage gained, the rotating target tube becomes the effective solution to the basic problem of sharpness of detail.

A single-focus rotating-anode tube which has an effective focal spot of 1.2 millimeters can be considered ideal for 200-milliampere apparatus. Its rating is amazingly high and all radiographic work can be done between 100 and 200 milliamperes. Despite its small effective focal spot size, its rating is greater than that of the largest focal spot of any stationary anode tube available. Because of its high rating, it is unnecessary to make use of the double focus principle with apparatus of 200-milliampere capacity.

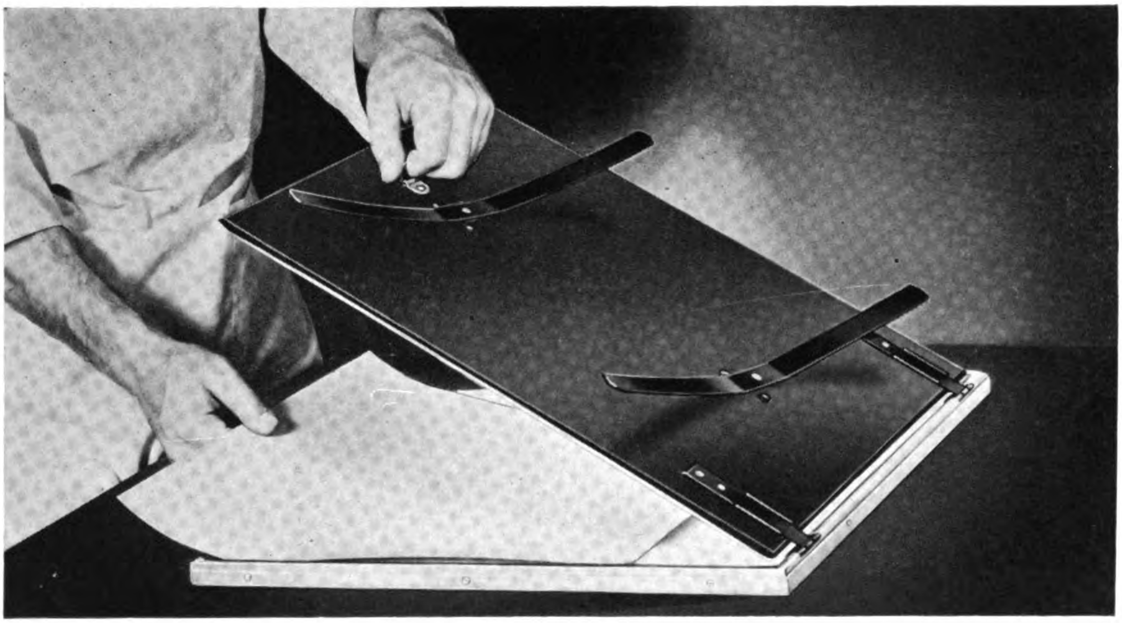

FIG. 96. Cassette with two intensifying screens.

C. Intensifying Screens

Röntgen's earliest observations on the properties of this then newly discovered x-ray were concerned with the excitation of visible light from chemical crystals subjected to x-ray bombardment. It was, as a matter of historical fact, this fluorescence from a paper surface coated with barium platino-cyanide that initiated his surmise of some unknown form of radiation as its cause.

The researchers of that time were not long in recognizing that a surface of chemicals placed behind the photographic plate would, by its light emission, intensify the effect of x-radiation which had already done its work on the sensitized plate.

Intensifying screens are layers of fluorescent chemicals which, in modern practice, are placed in contact with both surfaces of the x-ray film and affect the sensitized emulsion by giving off light. Figure 96 is a photograph of a cassette employing two intensifying screens in a light-tight container, the front screen in this case being less absorptive than the back screen. This fact, incidentally, is usually true. Figure 97 shows the cumulative effect of x-ray and light on the film.

Present day films of the type used with intensifying screens are selectively sensitive to the blue, violet, and near ultraviolet radiation given off by calcium tungstate, a chemical in common use. So marked is its effect that the light given off by the screens actually produces far more density on the film than does the x-radiation itself. Experiments show that under some conditions less than 2 per cent of the film-blackening effect is caused by the x-ray beam, and more than 98 per cent by the fluorescent light given off by the screens. For a given density in this case, the actual amount of x-ray energy could be reduced to about 2 per cent or 1/50 of that re-

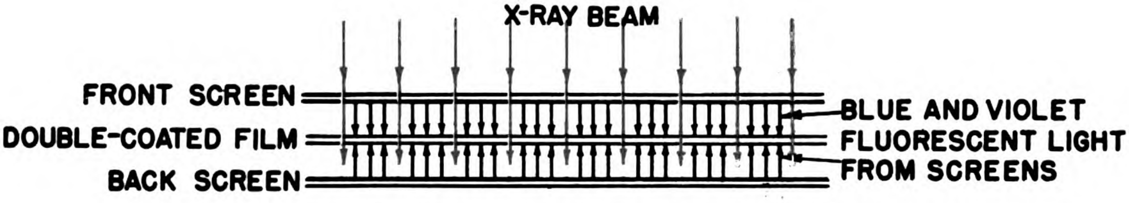

FIG. 97. Diagram showing the cumulative effect of x-ray and fluorescent light on the film.

quired if no intensifying screens were employed.

Intensifying screens are used primarily to reduce x-ray energy. This could be in the form of voltage, milliamperage, in time, and in some instances all three of them. The amount by which x-ray energy may be decreased for a given film density is the function of kilovolts peak and the speed of the intensifying screens.

The tabulation, Figure 98, is the approximate intensifying ratio for Patterson Parspeed screens at various tube voltages. The figures given represent screen constants which can be defined as the ratio in exposure time for densities with and without double screens. *This ratio applies only when using regular film.*

Kilovolts Peak	*K "Screen Constant"*
30	10
40	20
60	35
80	40
100	50

FIG. 98. Approximate screen constants for Parspeed screens in comparison to regular films without screens.

It is evident from the above tabulation that there is no ***particular*** screen factor. The x-ray wavelength exerts such an influence on the quantity and character of light emitted by the fluorescing crystals, that wide variations in intensification occur. In the voltage range of diagnostic radiography, that is, to 100 kilovolts peak, the screen constant increases with increase of voltage. The relationship is not a straight line as indicated in the approximate figures of the table, but a complex curve thus determined by actual tests.

Another factor which affects the amount of light given off by intensifying screens is the size of crystals which constitute its surface. The emanation increases with the increase in the size of these crystals, a variable which can be controlled only in the manufacturing process. It might appear then that the most desirable screen would be one that permits the shortest possible exposure time.

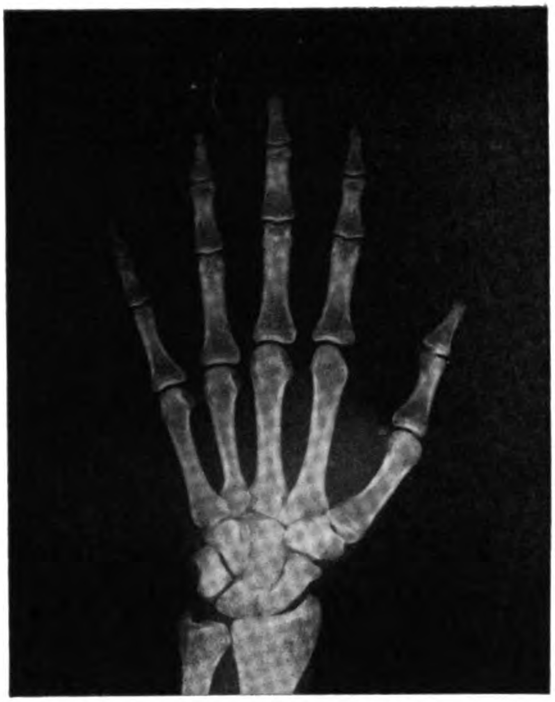

FIG. 100. Radiograph of a hand taken without intensifying screens.

The next consideration is the effect of intensifying screens on detail sharpness. The scattering effect of large chemical grains diffuses the image in a manner shown in Figure 99. The sharp lines become blurred by scattered light and the detail less easily discernible as crystal size is

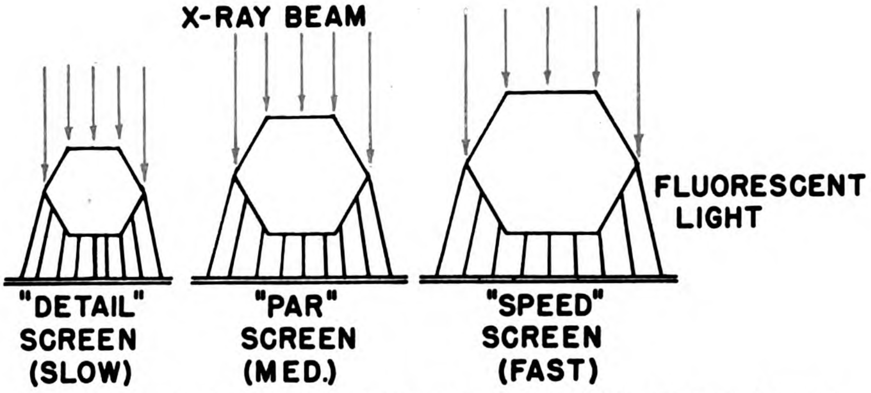

FIG. 99. Diagram showing relative light scattering effect of different types of screens.

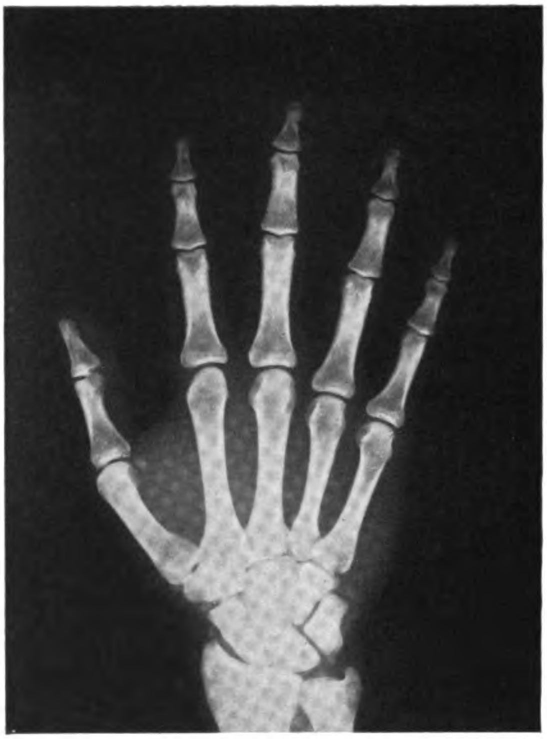

FIG. 101. Radiograph of a hand taken with high speed screens.

increased. Figure 100 is a radiograph of a hand taken without intensifying screens. Figure 101 is a radiograph taken with high speed screens in 1/40 the time. The difference in detail sharpness is more evident in the original radiographs, but it is not so apparent in the reproductions. To produce the best possible result, manufacturers have found it desirable to offer a variety of screens to permit compromise between speed and detail, consistent with the capacity of the x-ray energizing apparatus employed as well as the x-ray tube. These are:

1. Hi-speed screens. Best used with equipment having a capacity of 30 milliamperes or less.
2. Parspeed screens. Best used with equipment having a capacity of 100 milliamperes or higher. The detail is superior to that obtained with Hi-speed screens, but the intensifying factor is reduced.
3. Detail screens. Best used for extremities, head, and spine work, where utmost detail is desired and where sufficient power is available to keep exposure time within reasonable limits. These may be used in combination with Hi-speed or Parspeed screens for special application. The detail is superior to that obtained with Hi-speed or Parspeed screens, but there is a considerable difference in speed.

Recently it has been found that it is of great importance to note that the *temperature* of the screens has an appreciable effect on their speed or intensifying action, and within the limit of variation normally encountered, a factor of some importance.

A recent study of screen behavior between 50 degrees F. and 120 degrees F. is summarized in Figures 102, 103, and 104. From the first of these it is seen that at 50 degrees F. the speed relative to 75 degrees F. is 122 per cent. At 115 degrees F. it is 62 per cent. Expressing these ratios in terms of relative milliampere-seconds required for equal densities, Figure 103, 8 milliampere-seconds at 50 degrees F. is equivalent to 10 milliampere-seconds at 75 degrees F., and 18 milliampere-seconds at 120 degrees F. From a practical viewpoint, the curve, Figure 104, is most useful, since it expresses the kilovolts peak compensation to maintain constant density at

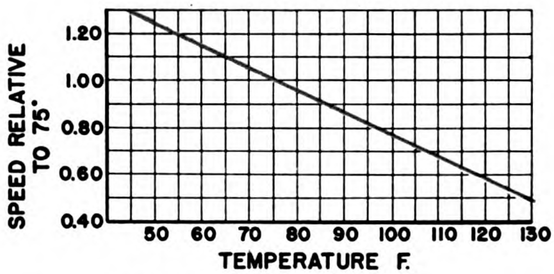

FIG. 102. Variation of intensity of fluorescence of Parspeed screens with temperature.

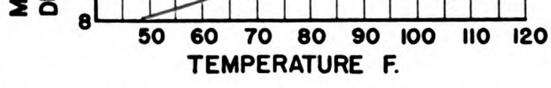

FIG. 103. Milliampere-seconds required at different temperatures for constant film density with Parspeed screens.

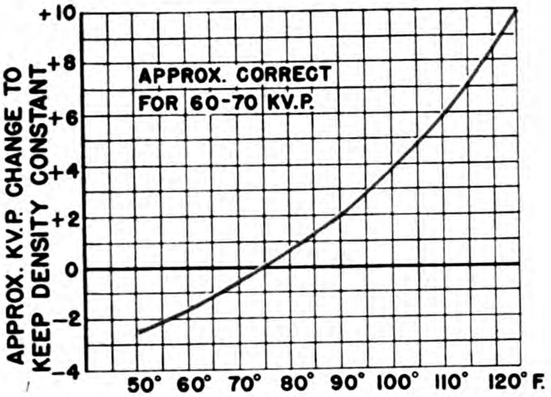

FIG. 104. Kilovolts peak change with temperature to maintain constant film density with Parspeed screens.

various screen temperatures. At 50 degrees F., 2½ kilovolts peak must be subtracted from the correct technic at 75 degrees F.; at 120 degrees F., 8½ kilovolts peak must be added.

Other data not shown indicates that practically all change in the speed is associated with the screens rather than the film. It was found that without screens, the speed is constant over the range indicated to within plus or minus 5 per cent. At the temperature of liquid air, −183 degrees C., the speed is 85 per cent of that at 75 degrees F., and in this case the film rather than the screen accounts for most, if not all, of the loss of speed.

It has been shown that the use of intensifying screens always produces some diffusion of detail in the radiograph. Screens are required, however, despite their effect on detail sharpness, because they permit radiography of many areas of the body whose opacity would otherwise make necessary x-ray energies dangerous to the patient and to the apparatus. Where motion is a problem, intensifying screens reduce exposure time values by a factor of 1/20 to 1/50 that which would be employed if no screens were used. It can be concluded that for all but the least absorptive parts of the body, and for all regions where unsharpness due to motion is a problem, intensifying screens with their accompanying diffusion effect are a necessity.

D. Non-Screen Radiography

Accepting these limitations, radiography without intensifying screens will be described as follows:

1. Employing regular film.
2. Employing the non-screen type of film made specifically for use without screens.

1. Regular Film

There is no common name to designate the conventional x-ray film which is ordinarily used at present. By mutual acceptance and understanding it is referred to as "regular" film.

The progressive stages in the development of the present regular film have been in the direction of increasing its sensitivity, not to x-ray wavelengths, but to the blue, violet, and ultraviolet spectra excited in the fluorescing chemicals of intensifying screens by x-rays. This is primarily a screen film which can be used without screens if considerable additional energy is utilized. Such requirements limit the use of screenless procedures with this type of film to the less opaque areas of the body, the extremity group. Figure 105 shows the approximate factors which could be utilized for a patient of average size.

Region	*View*	*Kilovolts Peak*
Ankle	Lateral	54
Knee	Lateral	66
Knee	Antero-posterior	72
Wrist	Postero-Anterior	48

Constant Factors—100 milliampere-seconds, 40-inch distance

FIG. 105. Approximate technical factors for extremities using regular film without screens.

It is evident from these values that the usefulness of such a technic is limited to parts of the body no more opaque than the knee, since even here a voltage value as high as 72 kilovolts peak is used for an average patient. Figure 106 is a radiograph of a postero-anterior knee, taken with regular film in a cardboard holder. Lack of contrast due to secondary radiation becomes the limiting factor in technic and establishes the extent of its practicability. It will be further noted from this table that the required exposure time is such that the utmost in coöperation from the patient is necessary. Technics used on uncoöperative patients require fractional-second exposures, thus making a screenless procedure with regular film impractical. The restriction of regular film to a portion of the extremity group and further to co-

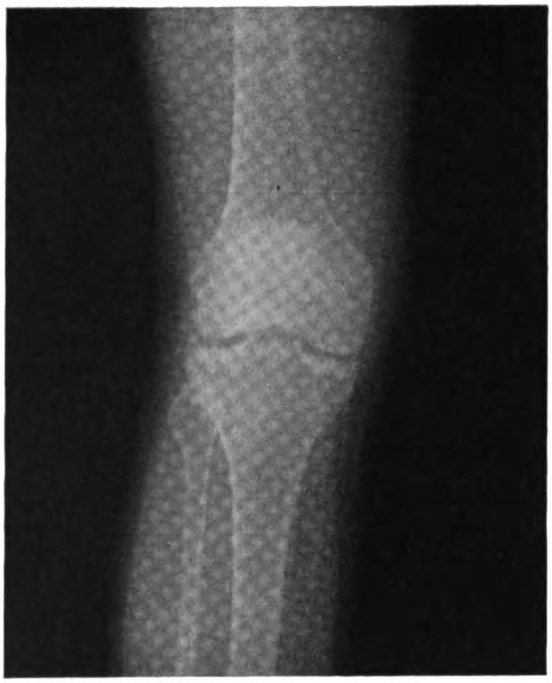

FIG. 106. Radiograph of a knee, postero-anterior, made with regular film in a cardboard holder.

operative patients has limited its usefulness. However, the improved sharpness of detail which results from its use is desirable so that technics approximating those shown in Figure 105 are frequently used.

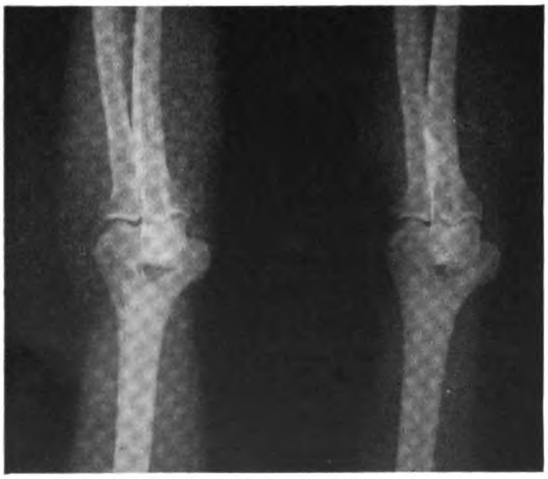

FIG. 107. (*Left*) Radiograph of an elbow, antero-posterior view, taken with regular film and no screens at 54 kilovolts peak.

FIG. 108. (*Right*) Radiograph of an elbow, antero-posterior view, taken with regular film and no screens at 60 kilovolts peak.

Another characteristic of the screenless procedure is its wider latitude to variations in penetration values. Using intensifying screens, a change of 3 kilovolts peak will ordinarily produce a visible change in density on the film. When the same type of film is used without screens, a change of 6 to 7 kilovolts peak is necessary in order to accomplish the same increase or decrease in density on the film. Figures 107 and 108 are radiographs of an antero-posterior elbow taken with regular film, no screens, at 54 and 60 kilovolts peak. Figures 109 and 110 are taken with screens at the same kilovolts peak values, with a suitable reduction in milliampere-seconds.

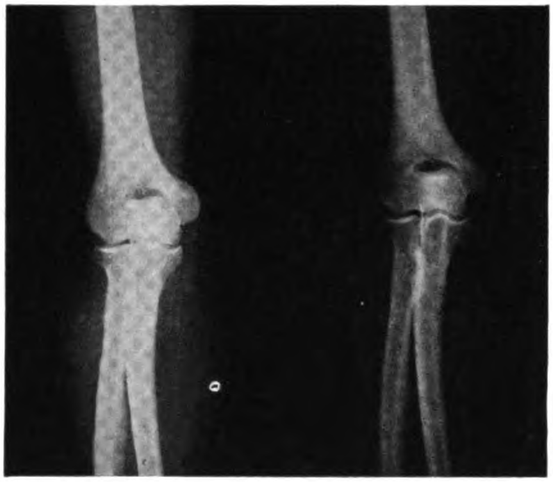

FIG. 109. (*Left*) Radiograph of an elbow, antero-posterior view, taken with regular film and screens at 54 kilovolts peak.

FIG. 110. (*Right*) Radiograph of an elbow, antero-posterior view, taken with regular film and screens at 60 kilovolts peak.

2. Non-Screen Type of Film

The non-screen type of film has been developed for the specific purpose of extending screenless procedures beyond the limits of the regular film. Being made specifically for use without screens, it is more sensitive to x-ray wavelengths than is the regular type of film, the speed ratio being approximately 4 to 1. For the same degree of density on the film, the time of exposure can be reduced to one-fourth, the milliamperage can be reduced to one-fourth, or the tube voltage can be reduced 12 to 16 kilovolts peak (depending on the initial value).

The increased sensitivity of this film makes possible the extension of non-screen radiography to heavier parts of the body because:

1. Lower kilovolts peak values can be used which causes a decrease in secondary radiation, resulting in improved contrast.
2. The Potter-Bucky diaphragm may be utilized without the necessity for increasing exposure values much beyond those used for regular film in cardboard holders without the Potter-Bucky diaphragm.

From Figure 111 it is seen that the shoulder may be radiographed using a lower kilovolts peak value than that employed for the knee with regular film. The improved contrast in the resulting film increases visibility of detail without increasing the time of exposure.

Region	*View*	*Kilovolts Peak*
Ankle	Lateral	40
Knee	Lateral	52
Knee	Antero-posterior	58
Shoulder	Antero-posterior	64
Wrist	Lateral	40

Constant Factors: 100 milliampere-seconds, 40-inch distance

FIG. 111. Approximate technical factors for extremities using non-screen film.

It becomes possible with the non-screen type of film to utilize the Potter-Bucky diaphragm for the heavier extremities and certain views of the spine, as indicated in Figure 112. The technics printed in the table, Figure 111, can be corrected to compensate for the use of most Potter-Bucky diaphragms by adding 13 to 16 kilovolts peak to the values shown. Figure 113 is a radiograph of a shoulder with non-screen type of film and the Potter-Bucky diaphragm using 100 milliampere-seconds and 70 kilovolts peak. The detail sharpness and wide latitude resulting from the use of this technic are clearly shown.

Region	*View*	*Kilovolts Peak*	*Distance*
Dorsal Spine	Antero-posterior	76	30 inches
Dorsal Spine	Lateral	76	30 inches
Cervical Spine	Antero-posterior	70	30 inches
Atlas and Axis	Antero-posterior	64	25 inches

Constant Factors: 200 milliampere-seconds

FIG. 112. Approximate technical factors for spine radiography using non-screen film and the Potter-Bucky diaphragm.

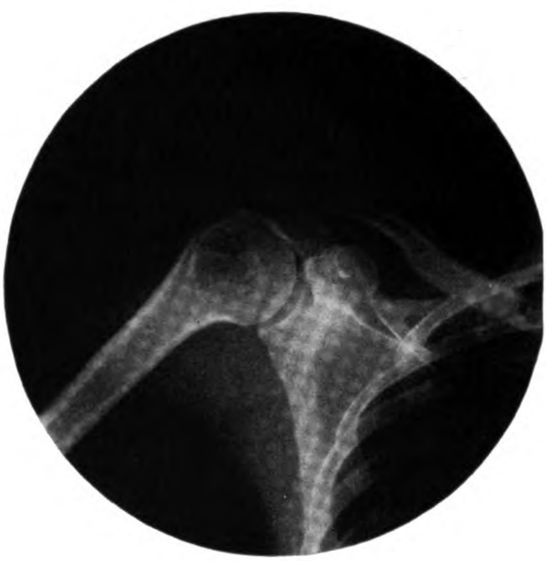

FIG. 113. Radiograph of a shoulder taken with non-screen film and the Potter-Bucky diaphragm, 100 milliampere-seconds, 70 kilovolts peak.

If equipment is available which permits a 300 or 400 milliampere-second technic in time of exposure sufficiently short to prevent motion, it is possible to extend non-screen technics with the Potter-Bucky diaphragm to parts heavier than those shown. Thus, a rotating-anode tube or a stationary-anode tube having a 2 millimeter focal spot operating from a full-wave generator* may permit 300 milliampere-seconds to be obtained in 3 seconds with a rotating-anode tube or in 10 seconds with the small focus of a stationary-anode tube.

Non-screen type of film requires longer time for processing. Development should be carried on for 7 minutes at 68 degrees F., or 5½ minutes at 70 degrees F. The films should be washed thoroughly after removal from the developer and allowed to remain in the fixing bath for from 10 to 15 minutes. If the film is to be viewed during development, it must be done by reflected rather than transmitted light, since the emulsion thickness is so great that very little transmission of light takes place through it. With its increased speed, wide latitude, and better contrast, non-screen type of film has great value in modern x-ray technic.

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* Consult tube rating chart.

E. Relation of X-Ray Source to Film

1. Position of Tube

With respect to any position except that directly under the center of the focal spot, the effective length or width of the focal spot will be altered, depending upon the relation of the object to the tube. This effect can be analyzed by reproducing the actual conditions in a typical case. Assume that the object is an anteroposterior pelvis radiographed on a 14 by 17 film at 40 inches, with the long dimension of the film and the axis of the tube lengthwise with the table, the x-ray tube in this case having a projected focal spot of 2 millimeters.

Figure 114 shows the effective projection along the 17-inch dimension of the film. Note that an angle of approximately 28 degrees is subtended. The length of the focal spot directly under the tube is 2 millimeters; at the end toward the cathode, 3.15 millimeters, and at the opposite end toward the anode of the tube, 0.75 millimeters. For example, in the radiography of a pelvis, with the cathode toward the patient's head, the iliac crests would be radiographed with a focal spot length more than 50 per cent greater than that directly over the center of the film and more than four times that employed for the femoral head. If, instead of the pelvis, the part were a lumbar spine, the same ratio would exist in comparing the first lumbar vertebra with the region of the sacrum. This change in focal spot configuration must be recognized especially where large film areas are to be covered. To minimize this effect, the relation of the part to the position of the tube, and the nature of the radiograph must be considered. For the pelvis, the change in definition from top to bottom is preferable to a marked change crosswise which may lead to a different appearance in the detail of the right and left sides. Figures 115 is a radiograph of a pelvis made with a 2-millimeter focal spot, the axis of the tube across the patient with the anode end over the right side. The difference in detail sharpness in the bone cancellous structure between the right and left sides is evident.

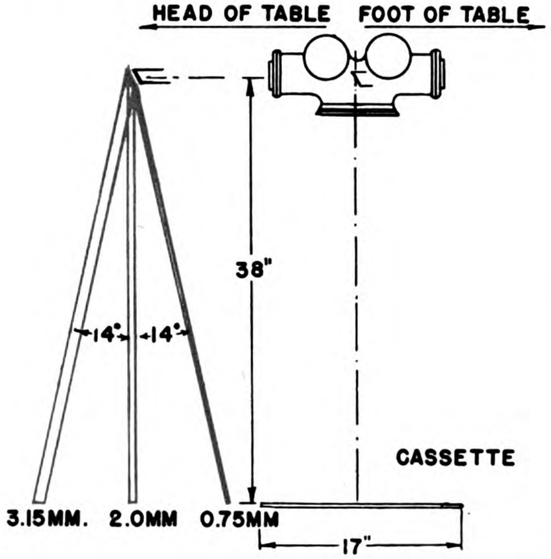

FIG. 114. Effective projection of focal spot along the axis of the tube.

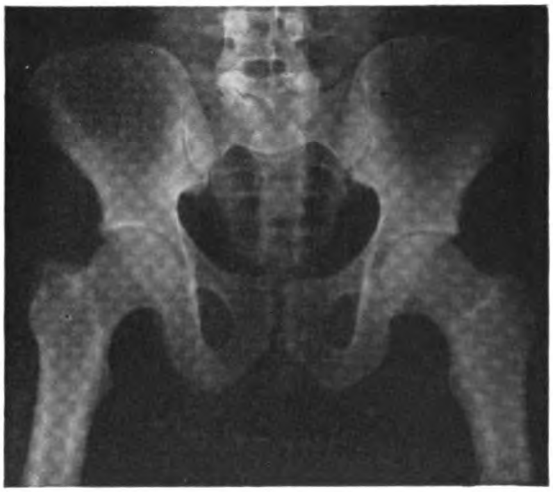

FIG. 115. Radiograph of a pelvis made with a 2 millimeter focal spot, axis of tube across the patient, anode end over the right side.

The effect of this change in focal spot configuration need cause no concern providing the proper relation between focal-film distance and size of area covered are given consideration.

The following tabulation of focal-film distance in relation to film size will be of assistance:

For focal-film distances of 25 inches to 30 inches, a film size of 8 by 10; 30 to 36 inches, a film size of 10 by 12; 36 to 40 inches, a film size of 14 by 17.

However, where larger film areas are to be covered at the closer distances, the effects are readily discernible and, unless identified, may affect the detail quality of the radiograph. Of particular importance in this connection is the asymmetrical change in length of the focal area from end to end of the x-ray tube as shown in Figure 114. The change in width, because of its symmetry, is less likely to be objectionable.

Another factor which influences the importance of this effect is the size of the focal spot employed. The examples were developed for a 2-millimeter focal spot. If a larger focal spot is utilized, the proportionate effect becomes greater. For example, if a focal spot 4.5 millimeters is used instead of the 2-millimeter focal spot, in Figure 114, the length of the focal spot directly under the tube would be 4.5 millimeters; at the cathode end of the film, 6.9 millimeters; and at the anode end of the film, 1.7 millimeters. To the eye, the disparity in detail sharpness between that portion of the radiograph taken where the 1.7-millimeter dimension is effective and that portion where the 6.9-millimeter length is effective, would be considerable.

2. Focal-Film Distance

Figure 116 illustrates the projection of a line with end-points P_1 and P_2 at the distance d_1 from the film surface shown at P_1' and P_2'. The x-ray tube has a focal area marked by the limits S_1 and S_2. Sharpness may be evaluated diagrammatically by the degree of disparity between the end-point projections from S_1 and S_2, indicated on the film plane by P_1' and P_2'. If P_1 or P_2 is projected as a point, then all lines in the body structure will be sharp. If the projections of P_1 or P_2 from S_1 and S_2 do not coincide on the film but form displaced images, the lines of structure appear as blurred areas.

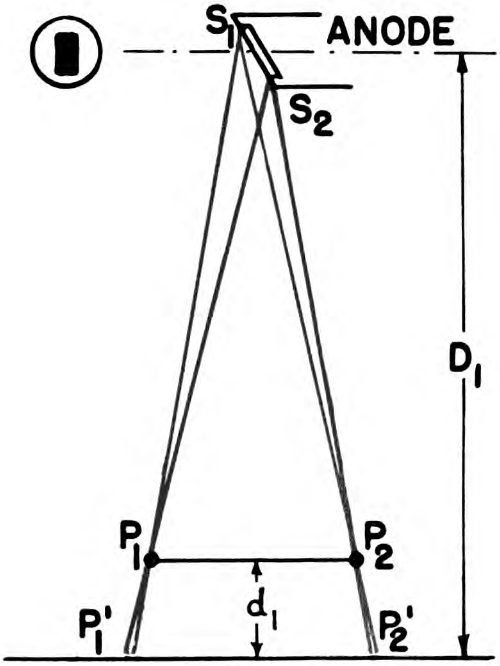

FIG. 116. Radiographic projection with large focal-film distance.

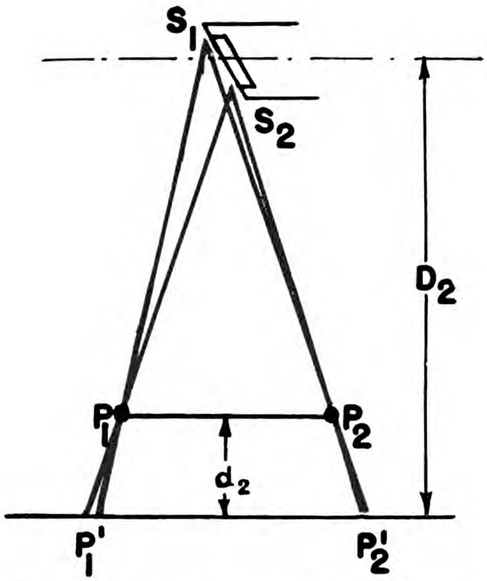

FIG. 117. Radiographic projection with shortened focal-film distance.

The problem is to investigate the effect of the focal-film distance D_1 on sharpness of detail in the radiograph. The focal-film distance D_1 is much greater than the object-film distance d_1. It is seen that the projections P_1' and P_2', though not points, represent but a small degree of blurring. The relationship in the diagram is that which would approximate a lateral lumbar spine and a focal-film distance of 40 inches. The focal area, however, has been made disproportionately large to permit illustration of double-image projection at this distance.

Figure 117 represents the effect of shortening the focal-film distance. The construction is identical except that D_2 is approximately half of D_1, Figure 116. It is plainly seen that the projection of P_1 is now diffused over a greater area on the film; P_2' is much sharper than P_1'. It is interesting to note that the projection of P_2, instead of suffering loss of sharpness as a result of the decreased distance, may actually be somewhat improved in one dimension because of the angle at which the radiation leaves the target. Due to the fact that we are approaching the angle of the anode itself, the projected length of the focal area decreases somewhat as indicated in Figure 117. For most radiographs, however, the decrease in focal-film distance is accompanied by a marked decrease in detail sharpness; this is represented by the projection P_1'. The increased angle at which x-radiation leaves the target results in projections of the focal area which effectively increases its size except, as has been mentioned, in some cases of grazing incidence toward the anode end of the tube.

All of this has a very immediate application in radiographic technic. Figure 118 is a radiograph of an antero-posterior hip taken at a focal-film distance of 25 inches. Figure 119 is a radiograph of the same part taken at 40 inches on the same individual. It is evident that increasing the focal-film distance will improve the detail sharpness of all lines in the object being radiographed. For radiography of the heavier extremities, shoulder, spine, chest, and internal organs, this is a desirable quality, reflected in the tendency in modern technics, to increase the distance utilized for these parts. The extent to which this can be done is limited by the ratings of tube focal spots, since increasing the focal-film distance necessitates increasing the quantity of x-radiation for a desired density within the time limitations of exposure for the part. The rotating-anode tube with its high rating and small focal spots offers tremendous advantages in this respect.

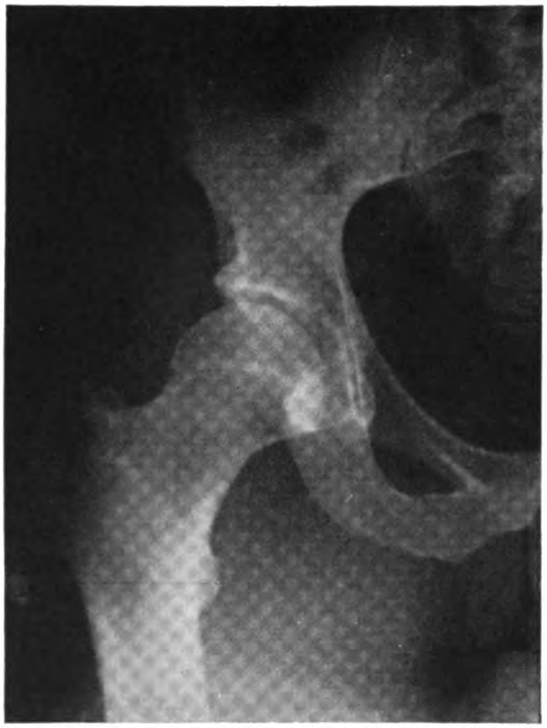

FIG. 118. Radiograph of an antero-posterior hip, focal-film distance 25 inches.

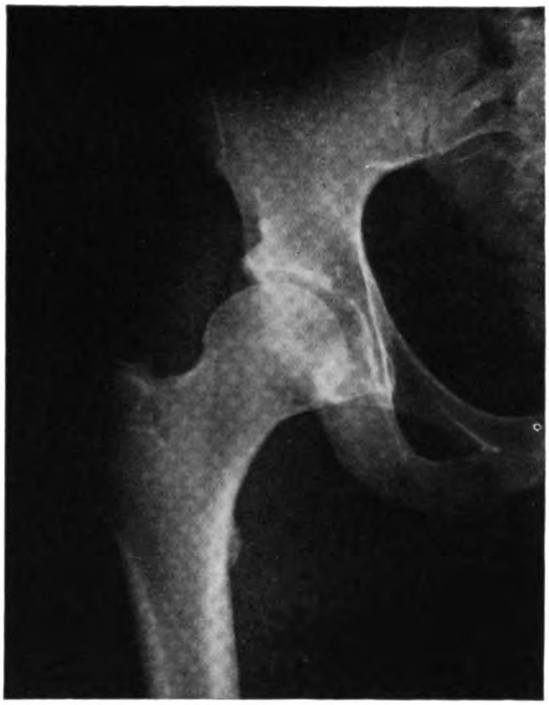

FIG. 119. Radiograph of an antero-posterior hip, focal-film distance 40 inches.

There are some instances in which the maximum detail sharpness for all parts of the object being radiographed does not result in the best radiograph. We may, by deliberately diffusing intervening structures, produce maximum differentiation in areas of particular interest. A good example is the skull. By using focal-film distances of 20 inches to 30 inches, which today may be considered as "close," those regions lying away from the film are blurred, and hence differentiation of the sharper structure close to the film is improved. The best mastoid technic utilizes a distance as close as 20 inches. Exposures for ribs are made with the area to be radiographed next to the film and a focal-film distance of 30 inches or less. The posterior ribs with the patient in the postero-anterior position are blurred and magnified, offering little interference to visibility of the anterior portion. The reverse is true for the antero-posterior position.

Where there is a problem in radiography which can be solved by rendering less sharp the detail of intervening structures, recognition of the effect of variation of focal-film distance may lead to a solution.

In summarizing it is found that:

1. Increasing the focal-film distance improves detail sharpness.
2. Improved sharpness obtained by increasing focal-film distance is limited by the rating of the x-ray tube and motion, since increasing the focal-film distance necessitates increasing energy to maintain the desired density.
3. Utilizing short focal-film distance solves certain problems in radiography because of resultant diffusion of detail in the portions of those parts at some distance from the film.
4. The reason for the effect of focal-film distance on detail sharpness is the accompanying change in the angle at which the x-radiation leaves the tube target. This angle determines the effective projection of the focal spot which produces differences in detail sharpness.

3. Object-Film Distance

In Figure 120 the end-points of a line representing a structural division of the object are projected to the plane of the film surface. The measure of detail sharpness is the degree of disparity between these end-point projections from the limit of the focal spot.

In this figure there is shown a projection for an object-film distance, d_1, which is proportionately small in comparison to the focal-film distance. Because of the small angle at which radiation from the focal area limits S_1 and S_2 leave the target, and end-points P_1 and P_2 produce double images P_1' and P_2', which are blurred but little. To the eye they would appear as sharp points, and the line of structure itself would be sharp. The relative distances in the diagram would correspond to the position of an elbow or lateral wrist with the tube 25 inches from the film. The focal spot is, however, disproportionately large to clarify the double projection.

Figure 121 shows the effect of an increase in

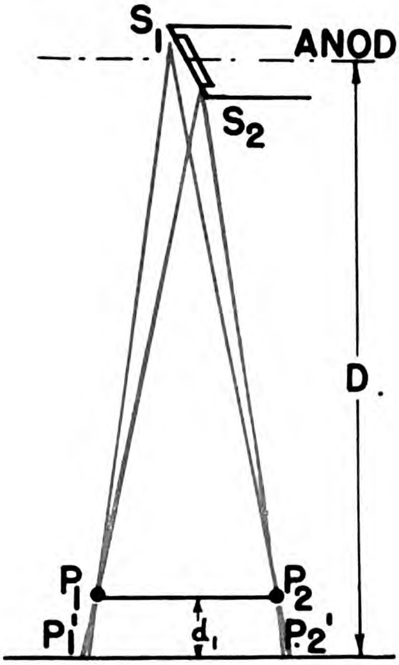

FIG. 120. Radiographic projection of point close to the film surface.

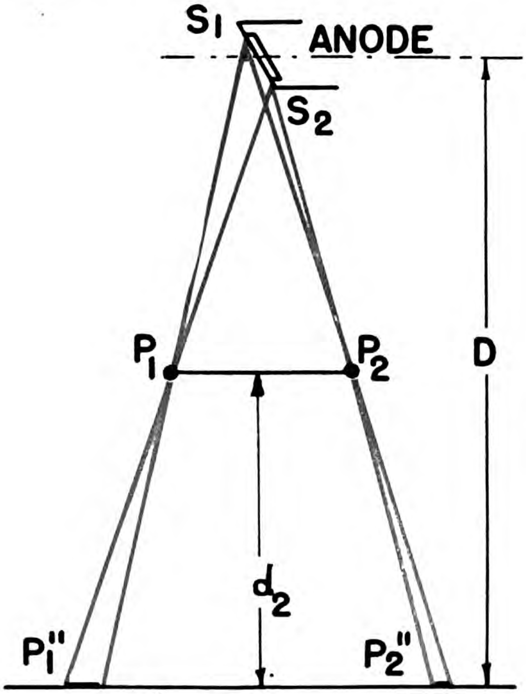

FIG. 121. Radiographic projection of point at an increased distance from the film surface.

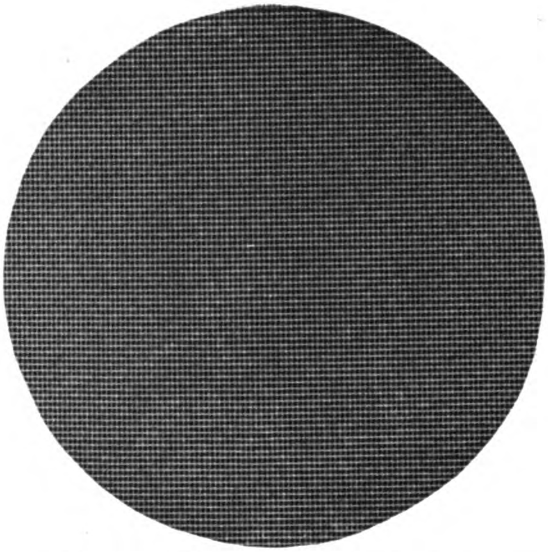

FIG. 122. Radiograph of wire mesh, short object-film distance.

object-film distance from d_1 to d_2, all other factors as in Figure 120. This change represents the relative position of a lateral lumbar spine on a fairly heavy patient, D again equal to 25 inches. P_1'' and P_2'' are diffused to a greater degree than P_1' and P_2' in Figure 120. The line of structure is blurred, and the radiograph lacks sharpness of detail. Note again that P_2'' is relatively sharper than P_1'', as an effect of radiation approaching the angle of the anode itself. Figure 122 is a radiograph of wire mesh, the object-film distance being relatively small. In Figure 123, the object-film distance is increased and the sharpness of detail visibly decreased.

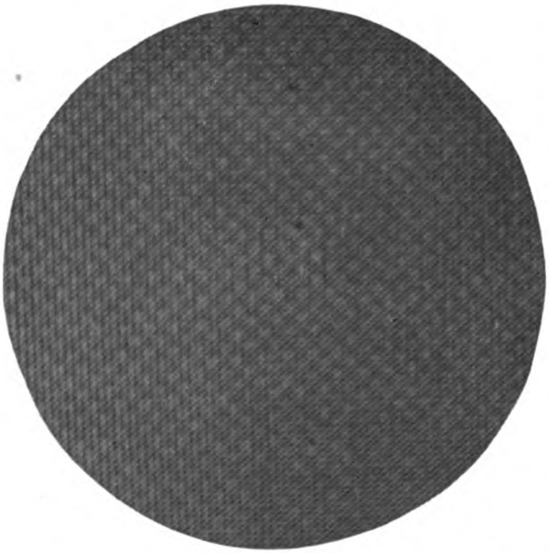

FIG. 123. Radiograph of wire mesh, increased object-film distance.

It is seen that the effect of size of focal spots becomes more marked in radiography of those parts of the body which, by their structure and position, must be at some distance from the film. For example, spines, particularly in lateral views, the gastro-intestinal tract, the genito-urinary system, and the lateral projection of the neck of the femur present problems because the object-film distance is generally from 4 to 10 inches and cannot be reduced. Since the very maximum in sharpness of detail is desired for these areas, one alternative is to increase the focal-film distance, another to employ a tube with a smaller focal spot.

F. Aberration of Detail

Another quality of the radiograph which must be analyzed is that characteristic which describes the truthfulness of rendition on the film of the size and shape of the structures being examined. The degree of variation of the film image with respect to the actual object is called aberration of detail and is dependent upon geometrical factors.

The simplest of the aberrations is magnification, resulting in increased image size due to projection of the x-ray beam through an object at a distance from the film. Radiographically the element of magnification is of great importance because it is present to some degree wherever the object being projected is not in immediate contact with the film. Figure 124 is a diagrammatic representation of the magnification resulting when an object, indicated by its end points P_1 and P_2, is at a distance d from the film. With the x-ray tube in position No. 1, corresponding to a focal-film distance D_1 approximately six times the object-film distance, the image size is given by the distance $P_1'P_2'$. It is evident that $P_1'P_2'$ is longer than P_1P_2. If the focal-film distance is decreased to approximately three times the object-film distance as shown by D_2, the resultant image is given by the distance $P_1''P_2''$ which is greater than $P_1'P_2'$. The magnification of the object has been increased by a reduction of the focal-film distance.

Figure 125 shows the effect of variation in

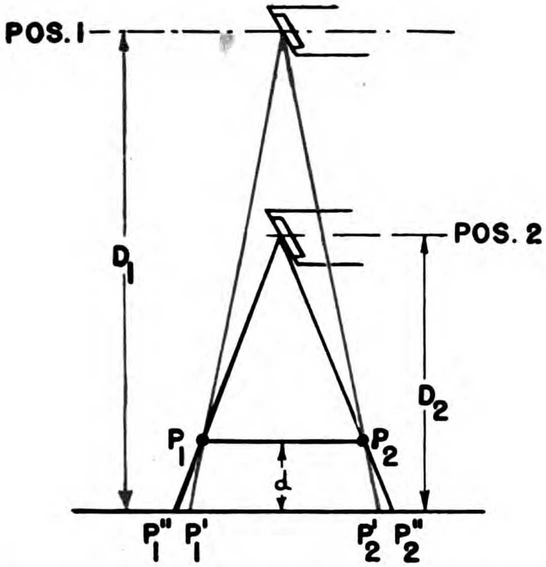

FIG. 124. Diagrammatic representation of magnification.

object-film distance on magnification, the focal-film distance remaining constant at D. When the object-film distance is increased from d_1 to d_2, the radiographic image increases in size from $P_1'P_2'$ to $P_1''P_2''$.

It can be concluded that magnification is affected by focal-film distance and/or object-film distance. By examination of the diagrams, it can be seen that a single function is really the determining one, this being *the angle of the primary beam*, P_1 or P_2, subtended by the end points of the object being filmed. When this angle is small, the magnification is small; when it is large, the magnification is correspondingly large.

It is of interest to derive the mathematical relations existing between the various factors thus far enumerated to permit calculation of object magnification.

Let D be the focal-film distance and d the

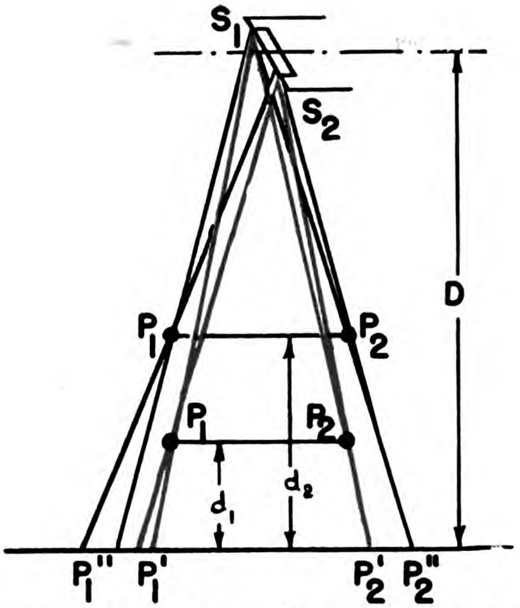

FIG. 125. Effect of object-film distance on magnification.

object-film distance. By the proportion of similar triangles,

$$\frac{P_1P_2}{D\text{-}d} = \frac{P_1'P_2'}{D}.$$

The ratio of $P_1'P_2'$ to P_1P_2 is the magnification factor. Solving the equation for the percentage magnification,

$$\%\ \text{mag.} = \frac{P_1'P_2' - P_1P_2}{P_1P_2} = \frac{P_1'P_2'}{P_1P_2} - 1 \times 100\%$$

$$= \frac{D}{D-d} - 1 \times 100\%.$$

Assume, in Figure 124, that D_1 is 36 inches and d is 6 inches. The percentage magnification, then, is

$$\frac{36}{36-6} - 1 \times 100\% = 20\%.$$

For the second case shown, assume D_2 is 18

PERCENTAGE OF MAGNIFIED RADIOGRAPHIC DISTORTION AT VARYING OBJECT-TO-FILM AND FOCAL-FILM DISTANCES

Object-Film Distance	*2 Ft.* %	*3 Ft.* %	*4 Ft.* %	*5 Ft.* %	*6 Ft.* %	*7 Ft.* %	*8 Ft.* %	*9 Ft.* %	*10 Ft.* %
1 in.	4.34	2.86	2.13	1.69	1.41	1.20	1.05	.93	.84
2 in.	9.05	5.88	4.35	3.45	2.85	2.44	2.13	1.89	1.69
3 in.	14.29	9.05	6.67	5.26	4.35	3.70	3.24	2.85	2.56
4 in.	20.00	12.50	9.05	7.14	5.88	5.00	4.35	3.85	3.45
5 in.	26.31	16.13	11.64	9.09	7.46	6.32	5.49	4.85	4.35
6 in.	33.33	20.00	14.29	11.11	9.09	7.69	6.67	5.88	5.26
7 in.	41.18	24.14	17.07	13.27	10.77	9.11	7.86	6.93	6.19
8 in.	50.00	28.57	20.00	15.38	12.49	10.53	9.09	8.00	7.14

inches and d, as before, is 6 inches. Then the percentage magnification is

$$\frac{18}{18-6} - 1 \times 100\% = 50\%.$$

For the variations illustrated in Figure 125, let d_2 be 12 inches; d_1, 6 inches; and D, 36 inches. The respective magnifications for the object-film distances d_1 and d_2 are 20 per cent and 50 per cent, as in the preceding illustration, Figure 124, in which the focal-film distance was changed and the object-film distance remained constant.

Using the simple formula derived above, the table on page 91 has been calculated for all focal-film and object-film distances normally encountered.

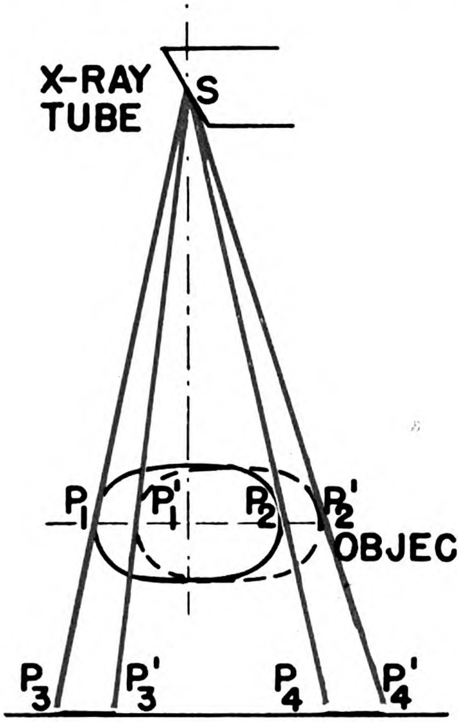

FIG. 126. Diagram illustrating the effect of motion on detail sharpness.

G. Motion

In common, the factors discussed are structural or mechanical in nature, fixed by the size of tube focal spot, the type of intensifying screens, focal-film distance, object-film distance, relationship of tube, object, and film, and magnification. As such, considerable control may be exercised in the selection and variation of these elements (object-film distance excepted), within limits established by economic necessity and flexibility of available equipment. The factor of motion, which is neither geometrical nor mechanical, with little susceptibility of control, but one which is extremely important in its effect on detail sharpness, must be discussed.

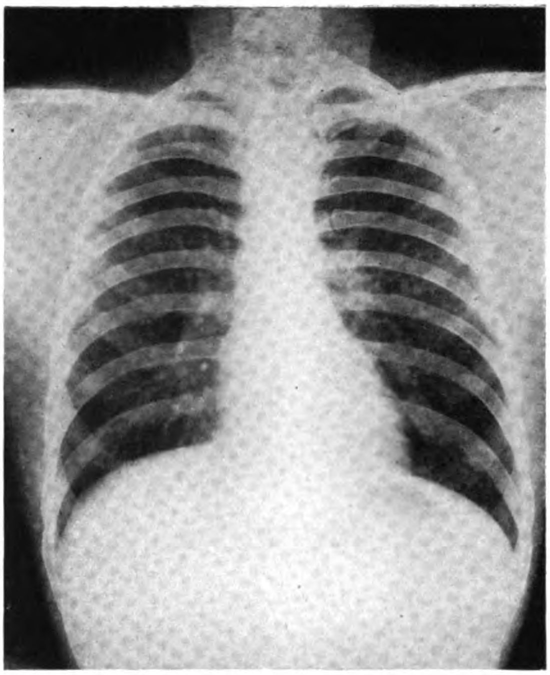

FIG. 127. Radiograph of a chest, time of exposure 1 second, showing the effect of motion on detail sharpness.

The diagram, Figure 126, illustrates the effect of object motion on detail sharpness. The original position is marked by the end points P_1 and P_2, these points being projected to the film at P_3 and P_4. If the tube, object, and film remain fixed in relative positions during the exposure, P_3 and P_4 will be sharp to an extent determined, as we have seen, by the size of the tube focal spot and the relative distances from tube to object to film. If the object moves, however, to a new position as shown by the dotted figures $P_1'P_2'$, its projection on the film will then take a position within the end points P_3' and P_4'. The detail structure is considerably blurred as a result since the limiting edges are not sharp lines, but broad bands shown as $P_3 - P_3'$ and $P_4 - P_4'$. The diagnostic quality of the radiograph is materially affected by motion of the object. This same result will follow for motion of the tube or the film during the exposure. Figure 127 is a radiograph of a chest taken with a time of exposure of 1 second to show the effect of motion on detail sharpness. Note that the lung structure is very poorly defined, particularly in the region of the heart.

The problem of motion may be simplified by an analysis of the various forms of its occurrence. The solution should come from recognition of the various types of motion as a means for minimization, if not control, of their effect.

Involuntary motion of the internal organs may be considered as one type. Movement of the heart, the displacement caused by motion of the diaphragm in respiration, the peristaltic action of the stomach and colon, the sudden shift in tremor and spasm, are examples of involuntary motion which, with the possible exception of respiration, are beyond the control of patient or technician. In radiography of the chest, the patient may stop breathing, but lung displacement caused by heart action will affect detail sharpness in adjacent areas. In radiography of the stomach, suspended respiration is of help, but peristalsis will blur the detail. The gall bladder and kidney will be shifted by diaphragmatic motion.

To minimize the effect of involuntary motion, the exposure time must be short. The following values are an indication of the relative times beyond which motion may be excessive:

Chest and Heart	1/10 second or less
Stomach	1/2 second or less
Colon	1 second or less
Gall Bladder	1 second or less
Genito-Urinary Tract	2 seconds or less

Exposure times materially longer than these will result, for most patients, in visible motion to an undesirable degree in the radiograph. The use of short exposure time requires energizing equipment of high capacity and x-ray tubes with focal spots sufficiently large to dissipate high energy in short time. A compromise must thus be effected betweeen loss of detail due to focal spot size and loss of detail due to motion.

Another type of motion which may be controlled is the voluntary type. The classification is not a rigid one, but includes the following radiographic groups:

- Extremities
- Head and Sinuses
- Pelvis and Spine
- Ribs

In the above, relatively long exposures may be utilized with coöperative patients, since the inference in classification is that motion is controlled by the patient, and proper immobilization.

In the voluntary motion group, exposure values indicated in the following table may be employed:

Extremities	5 seconds or less
Head and Sinuses	5 seconds or less
Pelvis and Spine	30 seconds or less
Ribs	5 seconds or less

X-ray tubes with small focal spots may be utilized because the permissible exposure is sufficiently long. The desirable maximum detail sharpness in bone structure is then a possibility. It is necessary, despite the word "voluntary," to employ devices for immobilizing the patient. Compression bands, sandbags, and immobilizing cones should be considered as necessities.

A classification is necessary with reference to the patient who cannot or will not coöperate. These are: the unconscious, demented, or intoxicated patients, and infants. Essentially the problem is one of involuntary motion and the time of exposure should be of the same approximate duration as that group.

For parts other than extremities, it is necessary to use high energy values and large focal spots to keep the exposure time within limits established by the possibility of motion. There is a loss of detail due to this requirement, but the net result is an improvement over a radiograph which shows considerable motion. The rotating-anode tube with its increase in permissible energy rating of as much as 600 per cent compared to the stationary anode tube of comparable focal spot size has an advantage in all radiographic work where involuntary motion is present and where noncoöperative patients must be handled.

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II. Visibility of Detail

A. Density and Contrast

IN THE previous chapter the terms density and contrast were introduced; *density,* as the degree of blackness on the film measured by the light absorption through it, and *contrast* as the difference in degree of blackness between adjacent areas.

Density may be evaluated photometrically and calculated as a function of the ratio of the amount of x-ray exposure on the film to the amount of light transmitted through it. A numerical figure can thus be obtained for any specified area on the film as an indication of the degree of blackness of that area. Contrast is not measured directly; it is computed as the numerical difference between the densities of film areas being compared. It is not necessary, however, to picture a radiologist seated before an illuminator with a photo-electric cell, microammeter, and slide rule, frantically calculating density and contrast so that he may decide if the radiograph is a satisfactory one. He is concerned with *visibility of elemental structures* as they stand out from regions surrounding them. The dye-filled gall bladder is visible, as an example, because of the difference in opacity which exists between it and the surrounding tissues. If the difference in density between it and the adjacent area is great, the contrast will be well-defined; the limit being established by all the factors affecting sharpness of detail. These have been discussed.

If the gall bladder area is the same density as the region around it, it will be indistinguishable. This the observer will immediately know though he may not attribute it to lack of contrast, nor may he be aware of the factors responsible. If the surrounding tissue is too light on the film, the gall bladder, being even more opaque when it is filled with dye, will be still lighter and may lack visibility. Finally, if the radiograph is generally too dark, the film density of its shadow may be so great that it will be to the eye as "black" as the less opaque material around it. The gall bladder will not be clearly visible despite the actual difference in opacity existing in the part.

From this example, it is evident that though contrast and density are separate concepts, they mutually affect the visibility of structure in the radiograph. It is actually this visibility which establishes the quality of the film, and it is only by this criterion that one can set the desirable degree of contrast and density. Another example will help to clarify this:

In radiography of the lungs, diagnosis may be difficult when the film is "flat" or "generally grey" in appearance. The details of structure are difficult to detect. To increase the degree of contrast in the radiograph, to make it more "black and white," it may be entirely possible to so vary technic with modern equipment that the basal portions of the lung become quite dark while the peripheral portions are too light. Such a film may be unsatisfactory because visibility of structure has been lost in some regions, though it may be quite true that those areas which are visible on the film are satisfactory. Between the film which is "too grey" and the film which is "too black and white" there is one which can be obtained by *proper selection of technic* to give the maximum visibility of structure. It may not be that which produces the maximum contrast, but rather that which gives *satisfactory* contrast. The chest radiographs A, B, and C illustrate three degrees of contrast.

Admittedly, there is something decidedly unscientific about the use of such a word as "satisfactory" in describing a quantity of anything. It is true, nevertheless, that because of differences in opinion, radiologists do not entirely agree on what constitutes a satisfactory degree of density or contrast in a radiograph. Most preferences fall in a comparatively narrow range, but individual choices as expressed, for instance, on a series of chest radiographs of the same patient, may vary

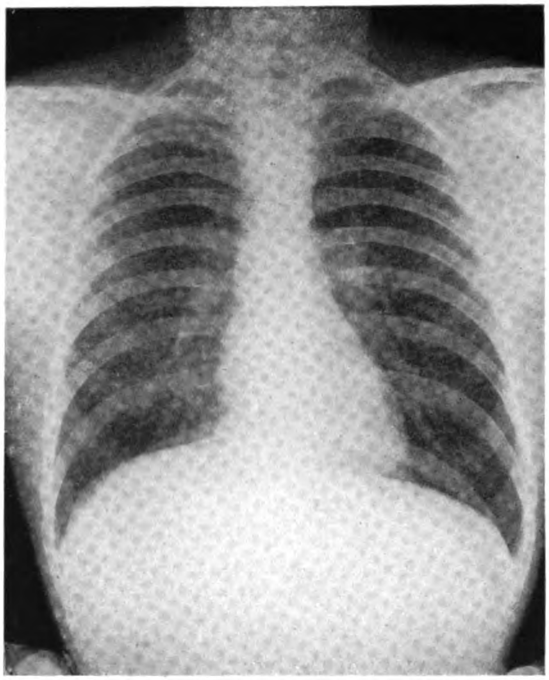

Illustration A. Radiograph of chest, 80 kilovolts peak, showing insufficient contrast.

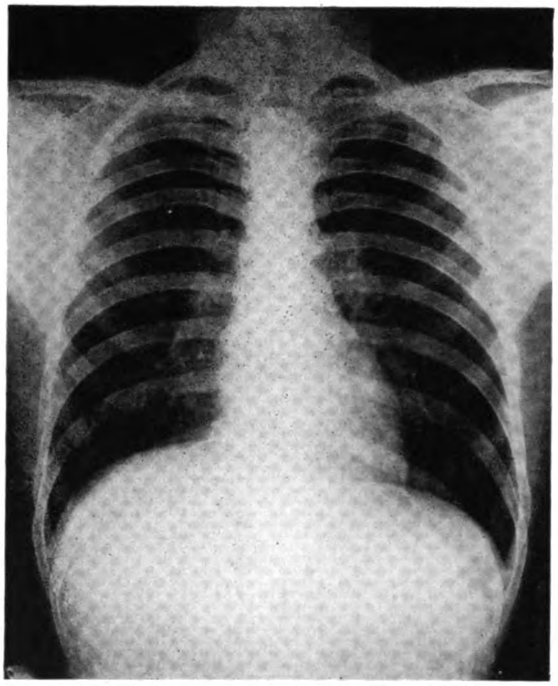

Illustration B. Radiograph of chest, 50 kilovolts peak, showing excessive contrast.

over a wide range. These preferences simply indicate the importance of recognition of such differences in any attempt to establish the "best technic." Since most of the radiographic factors affecting density in some measure act upon contrast, and vice versa, it will be convenient to discuss both jointly, but the distinction between the two is a very real one and must be kept in mind.

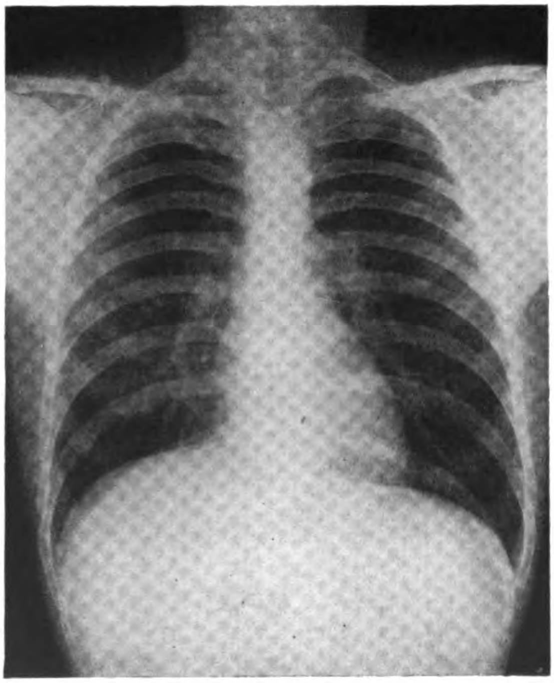

Illustration C. Radiograph of chest, 60 kilovolts peak, showing satisfactory contrast.

Effective Wavelength	*Per Cent of Radiation Transmitted*
0.2 Angstroms	85%
0.4 Angstroms	55%
0.6 Angstroms	15%

FIG. 128. Relation of effective wavelength of x-ray beam to per cent of radiation transmitted through 2 millimeters of aluminum.

B. Quality of Radiation

Of the various factors affecting density and contrast in the radiograph, that most widely used as a variable is the *x-ray tube voltage.* Modern x-ray machines are built with this in mind, the degree of selection being such that a finely divided control permits uniform increments of 1.0 to 2.5 kilovolts peak, corresponding to steps of the autotransformer.

The literature in x-ray physics from the time of Röntgen to the present day contains the results of numberless investigations made to determine the effect of tube voltage on the characteristics of x-radiation. Keeping in mind the fact that x-rays are a form of radiation similar to light except for their shorter wavelength, the relation of wavelength to applied voltage is of greatest importance.

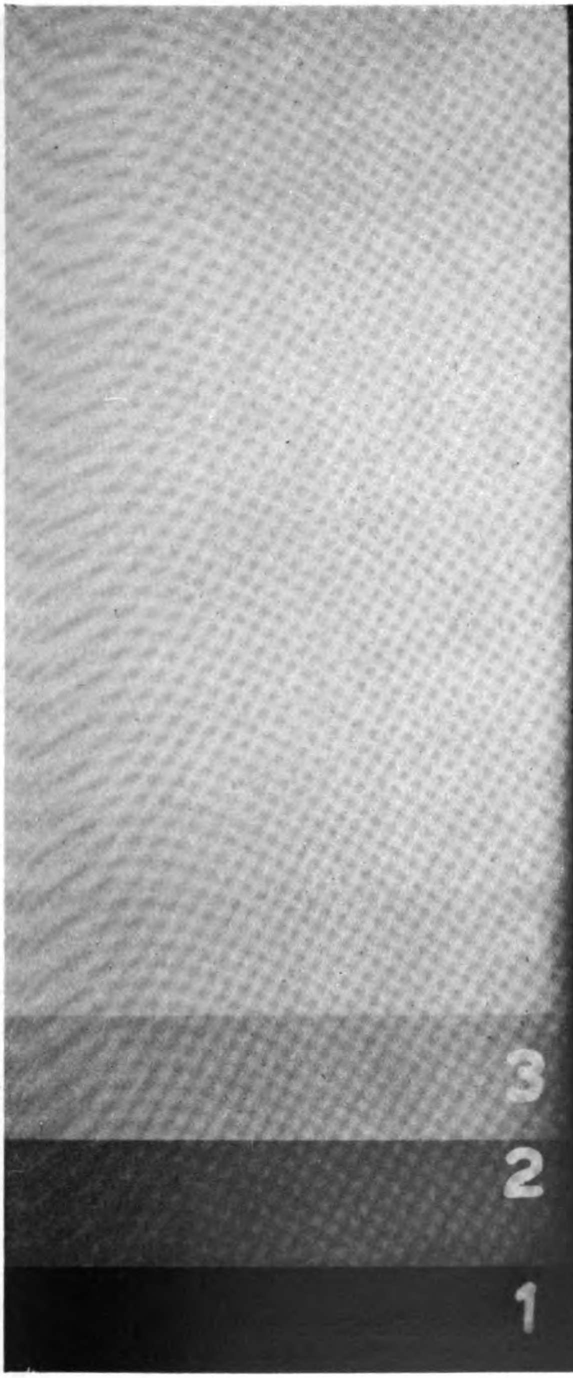

FIG. 129. Radiograph of an aluminum penetrometer taken at 40 kilovolts peak.

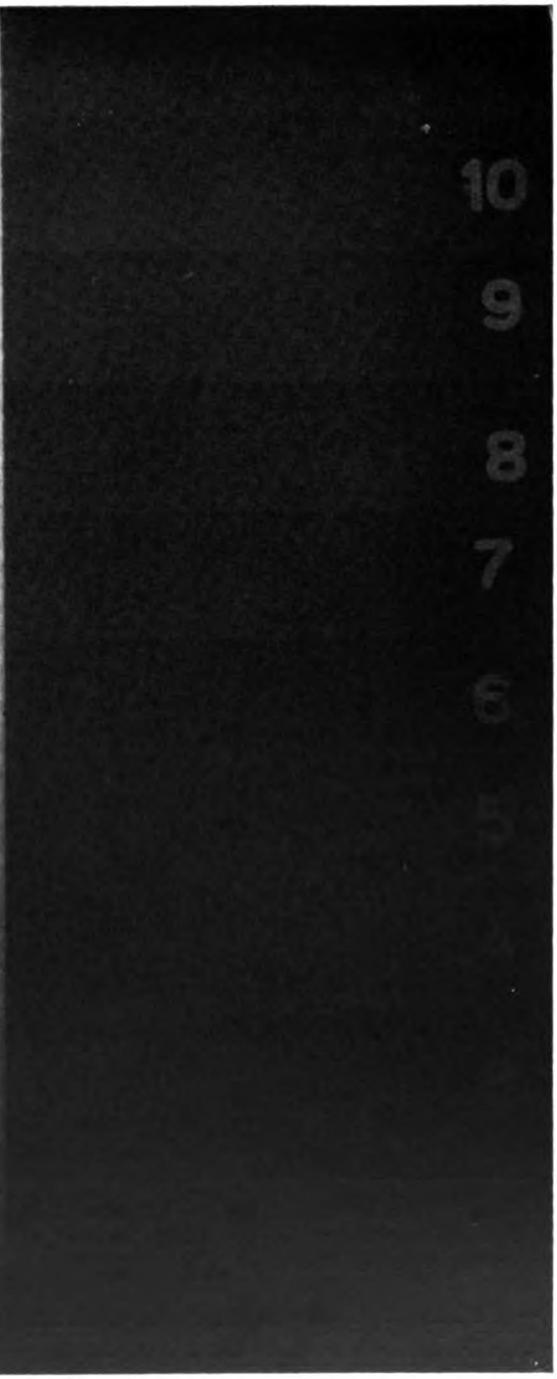

FIG. 130. Radiograph of an aluminum penetrometer taken at 80 kilovolts peak, same milliampere-second value as Figure 129.

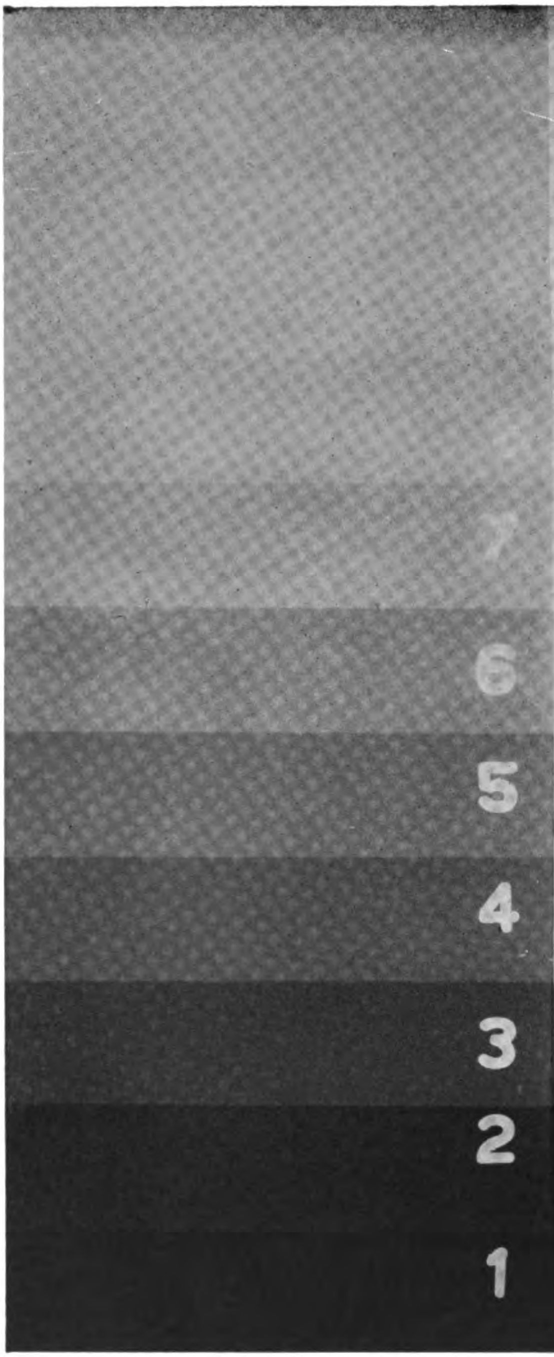

FIG. 131. Radiograph of an aluminum penetrometer taken at 80 kilovolts peak, milliampere-seconds reduced to compensate for increased density.

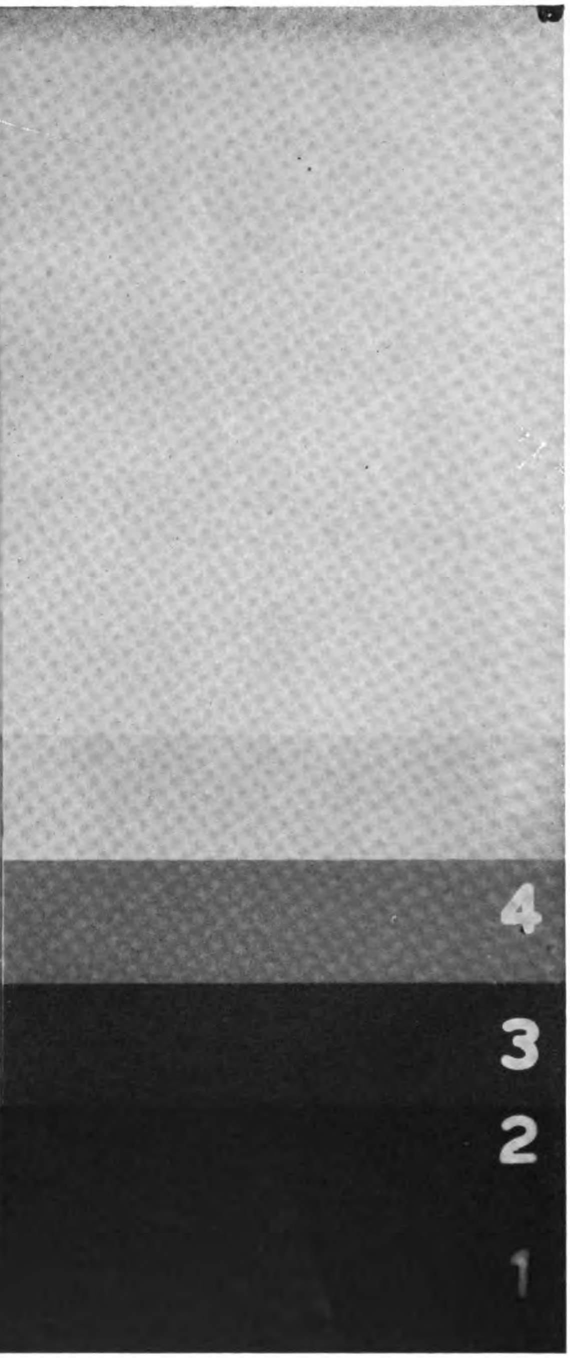

FIG. 132. Radiograph of an aluminum penetrometer taken at 40 kilovolts peak.

The x-rays generated by the x-ray tube are not of a single wavelength but have a wide range of wavelengths. The longer ones are easily absorbed and may not penetrate the walls of the x-ray tube. The shortest wavelengths are determined by the peak kilovoltage applied to the x-ray tube.

The relationship of x-ray absorption to wavelength is of interest. It has been found that all matter shows an absorption which depends on the wavelength of the x-ray beam. Figure 128 is the

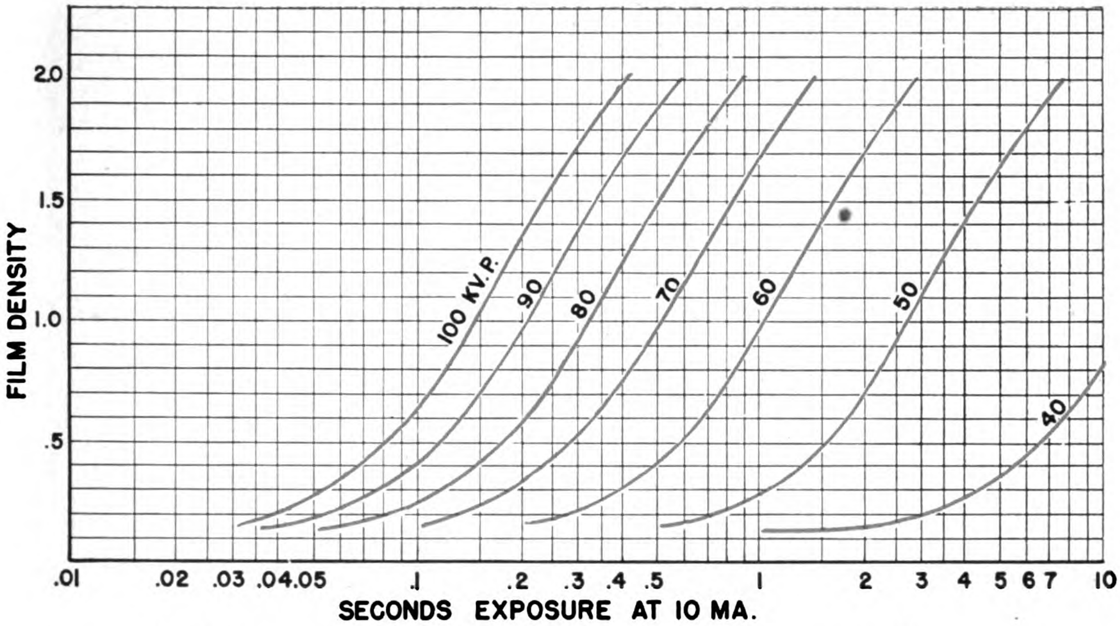

FIG. 133. Curves showing variation of film density with time of exposure for different tube voltages, with Parspeed screens.

data Duanne gives for 2 millimeters of aluminum.

It may be concluded that:

1. Increasing the voltage across the x-ray tube decreases the effective wavelength of the x-ray beam.
2. Increasing the tube voltage increases the intensity of the x-ray beam.
3. Increasing the voltage decreases the absorption of the beam in interposed matter.

From the radiographic point of view, these properties must be recognized as they affect the end result of density and contrast in the photographic emulsion. To further complicate matters, the photo-chemical sensitivity of the x-ray film and the fluorescent intensity of the intensifying screens varies with the wavelength of x-radiation.

An illustration of the overall effect of kilovoltage is shown in Figures 129 and 130, which are radiographs of an aluminum penetrometer having steps differing in thickness by 3 millimeters. Figure 129 was taken at 40 kilovolts peak and Figure 130 at 80 kilovolts peak, the milliampere-second values in both cases being the same. Note that the density of the 80 kilovolts peak film is much greater through equal thicknesses of the penetrometer.

Figures 131 and 132 are comparative films taken at 40 and 80 kilovolts peak, as before, but with a reduction in milliampere-seconds at the higher voltage. It is seen that the fourth step of the penetrometer in both films is of approximately the same density but that at the lower voltage the rate of change of density with changes in thickness is much greater.

Figure 133 is a series of curves showing the variation of film density with time of exposure for tube voltages from 40 to 100 kilovolts peak, all other factors remaining constant. The curves apply to the use of Parspeed intensifying screens and a filter of 14 millimeters of aluminum.

Note how the milliampere-seconds vary with kilovoltage for a constant film density. For example, for equal densities, 100 milliampere-seconds are required at 40 kilovolts peak whereas 2.6 milliampere-seconds are required at 80 kilovolts peak. Doubling the kilovoltage has reduced the required milliampere-seconds by a factor of approximately 40. Examine next the change in film density produced by a 10 kilovolts peak increase in tube voltage, keeping the milliampere-second value constant. For example, 68 milliampere-seconds at 40 kilovolts peak gives a density of 0.5. This same value of milliampere-seconds produces a density of 1.9 at 50 kilovolts peak. In a similar manner the data of Figure 134 have been obtained.

It is evident that the effect of tube voltage variation is much more pronounced at the lower voltages, a change of 10 kilovolts peak increasing the density by a factor of four at 40 kilovolts peak, two at 70 kilovolts peak, and about one and one-half at 90 kilovolts peak. All of this data applies to x-ray film with intensifying screens and a filter of 14 millimeters of aluminum.

By interpolation from the curves, it is also possible to determine the change in kilovolts peak required to compensate for a 50 per cent reduction in milliampere-seconds, Figure 135.

Although the increase in kilovoltage required to compensate for halving the milliampere-seconds varies with the initial kilovolts peak as indicated above, and with the thickness of filtration, for the usual technics in medical radiography, it is often sufficiently accurate to use the approximate value of 10 kilovolts peak, for kilovolts peak values between 55 and 80.

C. Milliampere-Seconds

The output of an x-ray tube is proportional to the total number of electrons traversing the interelectrode space and striking the anode. Since it is impractical to measure the total flow of electricity through the tube, the conventional procedure is to measure the rate of flow with a milliammeter, of such design and so connected in the circuit that it registers the average value of current passing through the tube.

It is advisable at this point to review some of the fundamentals of the operation of the x-ray generator, presented more completely in Chapter I.

The usual diagnostic x-ray unit is energized by a high tension transformer delivering a voltage changing cyclically in magnitude and direction somewhat as shown in Figure 43. In this figure, the character of the voltage pulsations applied to the rectifier or to the x-ray tube is shown. The time duration of each impulse is a function of the supply frequency, usually 60 cycles per second, so that the time is 1/120 second.

Initial Kilovolts Peak	*Milliampere-Seconds*	*Initial Density*	*Density after Adding 10 Kilovolts Peak*
40	68	0.5	1.9
50	15	0.5	1.4
60	6	0.5	1.16
70	3	0.5	0.9
80	1.8	0.5	0.85
90	1.2	0.5	0.80

FIG. 134. Effect of adding 10 kilovolts peak in changing film density.

Figure 44 shows the x-ray tube current resulting from the direct application of this voltage. Since the x-ray tube is a uni-directional device, the electron flow occurring only when the anode potential is positive with respect to the cathode, successive half-cycles of current flow are interrupted or "self-rectified." The shape of the current wave will differ from that of the transformer voltage because of x-ray tube characteristics but will always exhibit a periodic series of pulsations with alternate half-cycles absent. Figure 136 is a radiograph made of a spinning top, using a self-rectified x-ray generator. Operating on 60-cycle alternating current, the time duration is 1/10 second and six dots are evident.

Added Kilovolts Peak	*From*
4 Kilovolts peak	40
7 Kilovolts peak	50
10 Kilovolts peak	60
13 Kilovolts peak	70
16 Kilovolts peak	80

Based upon 14 millimeters of aluminum filtration

FIG. 135. Added kilovolts peak to compensate for 50 per cent reduction in milliampere-seconds at various kilovolts peak values.

If a mechanical or four-valve rectifier is employed between the high voltage transformer and x-ray tube, the current picture will change to that shown in Figure 52, wherein the previously "rectified-out" portion is brought in. Figure 137 is a spinning-top film made in 1/10 second on a 60-cycle, full-wave rectified equipment. Twelve dots appear. Note the difference in spacing between the dots for the two circuits.

From these diagrams it is evident that the energy to the x-ray tube is delivered in the form of regularly recurring impulses, each of a time-duration fixed by the frequency of the alternating-current supply. The milliammeter, however, due to the inertia of the moving element, cannot follow these rapid pulsations and it assumes an average deflection corresponding to the relative positions of the dotted lines in Figures 44 and 52. The relationship which this average value bears

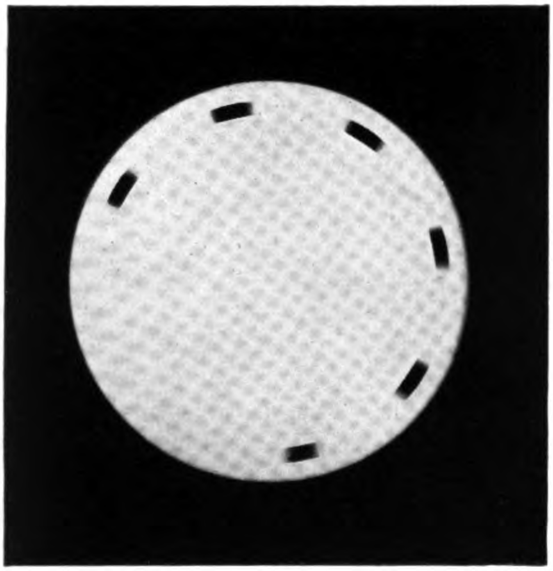

FIG. 136. Radiograph of a spinning-top for a 1/10-second exposure on a self-rectified x-ray generator.

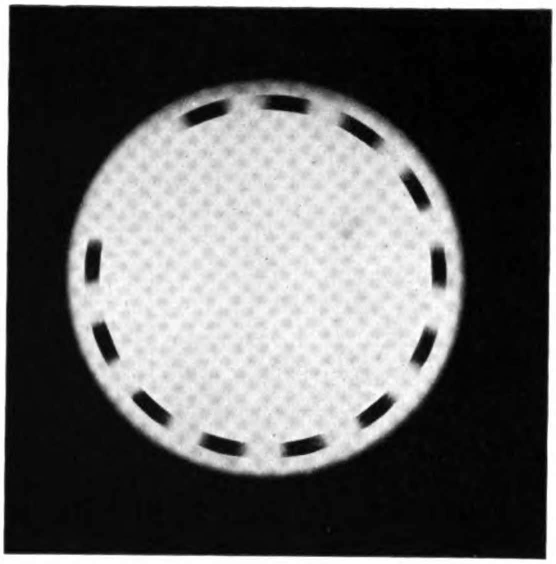

FIG. 137. Radiograph of a spinning-top for a 1/10-second exposure on a full-wave rectified generator.

to the maximum or peak tube current is dependent upon the shape of the current wave and can be determined graphically by integrating the area for a complete cycle and computing the ordinate for an equivalent rectangular area with a base equal to the time of a full cycle, or I_{av}.

In order to fully appreciate the function of the milliammeter and its limitations, it is important to recognize this condition. Fundamentally, the x-ray output from a tube is a summation of instantaneous values of current and voltage over each half cycle. The average value of current as indicated by the milliammeter does not completely define the nature of the x-ray beam even when accompanied by a statement of the peak kilovoltage. Both are merely practical expedients and the more complete expressions must convey some information as to the shape of the voltage and current waves.

If the relationship of the average milliampere value to the summation of instantaneous values remains constant over the total range of the x-ray generator, it is possible to use the milliammeter as an indicator of x-ray output and to definitely state that the two are directly proportional. It is only within the past few years that equipment of such design has been available. Due to deficiencies in earlier designs made apparent by improvements in the present type, increasing the tube current through the rated range of the transformer resulted in marked wave-form changes in current and voltage, particularly at the higher loadings. As a result, the x-ray output on some types of apparatus is not proportional to average tube current, the deviations from linear proportionality becoming increasingly pronounced at the higher milliampere values.

For some time it was believed that this deviation was due in some unaccountable manner to the characteristics of films and screens and their behavior at high milliamperage, short-time technics. As an example, on a 200-milliampere machine, a chest exposure of satisfactory density might be made with the following technical factors:

72″—100 milliamperes—1/10 second—(10 mas)—62 kilovolts peak.

If a similar radiograph were to be taken at 200 milliamperes and 1/20 second (10 mas), it might reasonably be expected that the same kilovolts peak value would result in a film of the same density and contrast.

Actually, the 200-milliampere film may be lighter, requiring an addition of 6 to 10 kilovolts peak to maintain the original density. With the higher kilovolts peak, the contrast is materially reduced and the 200-milliampere film is less satisfactory because of decreased visibility of detail.

Such performance was characteristic of older transformer design and has nothing whatsoever to do with film or screen performance. As the current through the transformer was increased, the x-ray output per milliampere decreased because of changes in wave shape with increased loading.

It is no longer necessary to accept such performance. A truly modern transformer incorporating basic improvements in its design will make possible uniformity of output over the entire range. With a 200-milliampere generator, similar outputs, as indicated by density and contrast in the radiograph, should be obtained with the following technic:

20 ma	1/2 second
40 ma	1/4 second
100 ma	1/10 second
200 ma	1/20 second

The same kilovolts peak is to be used in all cases.

The proportionality of x-ray output with tube current may be said to be linear, with a properly designed and correctly calibrated generator.

The variations of film density with milliampere-seconds is a less simple relationship, depending on the density value being considered, the characteristics of the film, the response of intensifying screens, and the time, temperature, and constitution of the developer. Figures 133 and 138 illustrate the variation in density with changes in x-ray exposure, as previously described. Figure 139 illustrates the change in density produced by doubling the milliampere-second value, starting with different densities.

Initial Density	*Final Density*
0.3	0.75
0.6	1.34
0.9	1.70
1.2	1.96

FIG. 139. Change in density produced by doubling the milliampere-second values, starting with different densities.

Doubling the exposure time doubles the film density in this particular case when the initial density is about 0.7. Since 0.7 is near the medium density, it can be said that in this range changes in film density are approximately in the same proportion as the changes in time of exposure or milliamperes.

It can be concluded that film density is variable with tube current and that the changes are approximately proportional.

D. High Milliampere Technic

High milliampere technics permit reduction in length of exposure time and minimize motion to the greatest possible extent in the interest of maximum sharpness of detail and in addition maintain satisfactory contrast.

A radiograph of the stomach made in ¼ sec-

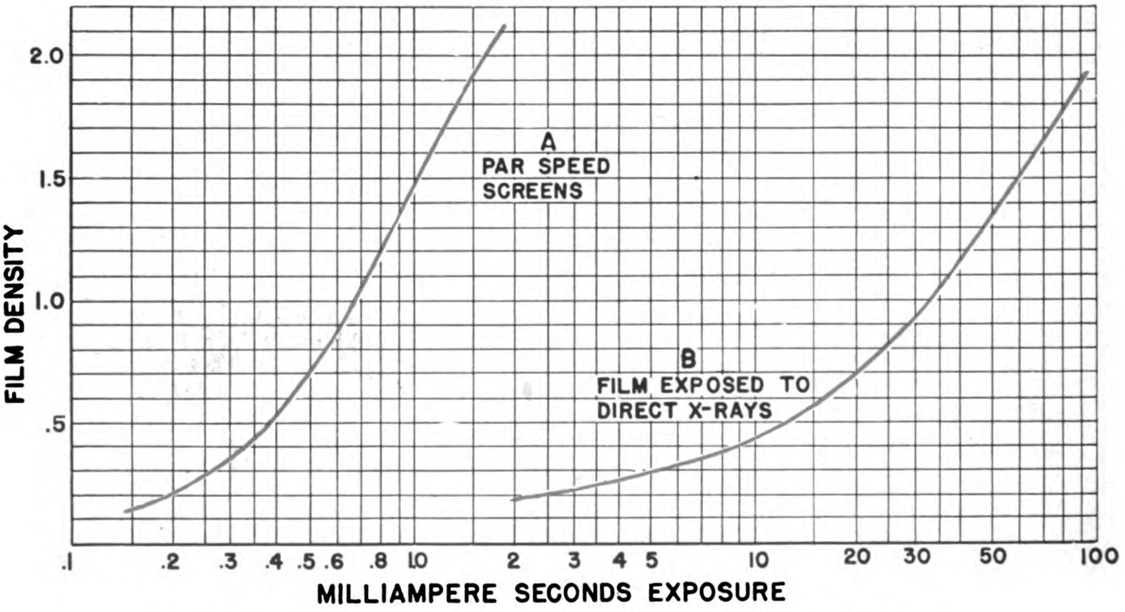

FIG. 138. Variation of film density with changes in milliampere-second values.

ond should be visibly sharper than if 1 second were used because of involuntary motion of the part. For comparable density and contrast in the two films, it will be necessary to use 300 milliamperes for ¼ second, while 75 milliamperes would be correct for the 1 second technic. With the same distance, the same tube voltage (kilovolts peak), identical cassette, films, and processing procedure, the first radiograph will convey to the observer a sharper outline of the barium-filled stomach, its motion arrested in a ¼ second exposure which has been made possible by the increased tube current.

The rating of the x-ray tube and transformer must be carefully examined to determine if the desired technic is within the limits of each. The transformer limitation is readily determined by reference to the machine calibration chart which, if correctly prepared, will indicate no voltage nor milliampere values in excess of its safe capacity. The x-ray tube, however, is much more susceptible to overloading and irreparable damage because of the nature of its use. For short-time exposures which accompany high-milliampere technics, the limitation is established by the focal spot temperature, this being a function of the electrical factors of voltage and current, the duration of application, and the size of the focal spot. *Reference to the tube rating chart for this information is mandatory.*

With the preceding example of a G-I technic of 75 milliampere-seconds, on a full-wave rectified circuit, a tube with an effective focal spot of 3.8 millimeters would safely stand 75 milliamperes for 1 second, but such a tube would be hopelessly damaged if 300 milliamperes for ¼ second were used at 60 to 70 kilovolts peak.

Even if a tube with an effective focal spot of 5.2 millimeters is selected, the technic is *dangerous,* since such a tube could not safely be used over 60 kilovolts peak at 300 milliamperes and ¼ second. The most practical solution is the rotating-anode tube which, with its 2 millimeter focal spot, *safely* permits the utilization of these values.

For each region of the body there is a milliampere-second value which will produce the most satisfactory radiograph. This specification is not sharply defined to narrow limits, but is based on the x-ray opacity of the body region, the distance from tube to film, the radiographic speed of the generator, and the characteristics of screens, film, and processing technic. Much of the mystery, and seemingly chaotic state of the usual technic chart, disappears when the analysis is made from this viewpoint. First, what milliampere-second value must be used to establish the tube voltage which, at a specified distance, will produce the desired degree of density and contrast? Second, with this milliampere-second value determined, what specific figures for time and milliamperes are to be utilized?

The first problem is one of the thickness of the intervening body structure and its radiographic opacity. The second problem is purely one of the rating of the x-ray tube and the energizing apparatus in which the limitations of either will establish the length of exposure time, this in turn affecting detail sharpness of the radiograph to an extent determined by the degree of motion of the part.

As an example of this approach, we may determine the technic to be used for radiography of the chest in the postero-anterior position.

The focal-film distance will be established at 72 inches, a commonly used figure because of the low degree of magnification resulting (less than 7 per cent). From the examination of large numbers of chest films for density and contrast, it has been found that with modern generating apparatus of high radiographic output, 10 to 25 milliampere-seconds and voltage values from 50 to 80 kilovolts peak will cover a range for adults with satisfactory contrast in the heaviest patients and not excessive contrast in the smallest. The density will remain constant as the voltage is varied to accommodate the opacity of each subject. Thus the first problem is solved and it remains to determine the specific values of time and tube current for the production of 10 to 25 milliampere-seconds.

For this information, refer to the tube rating chart and generator specifications supplied by the manufacturer. For illustration, the equipment is a 100-milliampere self-rectified machine. The tube used in conjunction is a shockproof double-focus tube with a small focal spot 2 millimeters and a large focal spot 4.5 millimeters.

Reference to the tube rating chart supplies the safe exposure values of which the following, Figure 140, are a random choice, at the maximum voltage rating of the tube using a self-rectified

Large Focal Spot		
85 kilovolts peak	100 milliamperes	2/10 second
85 kilovolts peak	75 milliamperes	1½ seconds
85 kilovolts peak	50 milliamperes	8 seconds
Small Focal Spot		
85 kilovolts peak	30 milliamperes	4/10 second
85 kilovolts peak	25 milliamperes	6 seconds

FIG. 140. Current and time ratings for a double-focus tube on a self-rectified circuit, 85 kilovolts peak (2-4.5 millimeters).

unit. The maximum voltage value should be used as the basis for selection because the safety factor, in utilizing a technic which is conservative, should be highest for the exceptional case.

From examination of these ratings it is seen that 10 milliampere-seconds can be obtained at 100 milliamperes and $\frac{1}{10}$ second with the large focal spot, or 30 milliamperes and $\frac{3}{10}$ second with the small. The density and contrast using either technic will be approximately the same but, from the standpoint of detail sharpness, it is necessary to decide whether $\frac{1}{10}$ second with a 4.5 millimeter focal spot or $\frac{3}{10}$ second with a 2 millimeter focal spot will produce a superior film. Again, only test and examination can supply the answer. General agreement holds that the $\frac{1}{10}$ second technic is better, the loss of detail due to focal spot size being less than the loss of detail due to motion.

The postero-anterior chest technic is then established:

Distance—72 inches
Current—100 milliamperes
Time—$\frac{1}{10}$ second
Voltage—50 to 80 kilovolts peak

In a similar manner, the time and tube current may be determined if a 2-4.5 double-focus tube is operated from a full-wave rectified circuit of 200 milliamperes capacity. The technic would be:

Distance—72 inches
Current—200 milliamperes
Time—$\frac{1}{20}$ second
Voltage—50 to 80 kilovolts peak

For other regions of the body, the same analysis is equally useful.

This analysis of x-ray technic is based on a study of energy factors required to produce a desired radiographic result within the capacity of the available x-ray equipment. The following conclusions can be stated:

For each region of the body there is a milliampere-second value which will produce the most satisfactory radiograph.

This value being based on:

a. X-ray opacity of the region.
b. Distance from tube to film.
c. Radiographic speed of generator.
d. Characteristics of screens and films.
e. Processing technic.
f. Individual preference of the diagnostician.

With the milliampere-second value determined, the specific values of time and tube current (milliamperage) will depend on:

a. Rating of x-ray tube.
b. Rating of x-ray generator.
c. Type and extent of motion of regions to be radiographed.

From this analysis it is evident that there are two elements which are basic for any radiographic procedure: the *first* of these is an empirical one dependent upon the thickness of the part and its opacity to x-ray. The *second* is a technical one dependent upon the capacity and rating of the x-ray equipment. The futility of the much-discussed question, "Is x-ray technic an art or a science?" becomes apparent with recognition of its dualistic nature; a non-science to the extent that the patient-variable exists, and a science as far as tube rating charts, calibration charts, and absorption curves will take us.

Region	*Distance*	*Milliampere-Seconds*
Chest	72 inches	10- 25
Extremities (screen)	40 inches	5- 15
Stomach	30 inches	50-150
Gall Bladder	30 inches	50-200
Colon	40 inches	100-200
Kidney	40 inches	100-200
Ureters	40 inches	100-200
Urinary Bladder	40 inches	100-200
Spine, antero-posterior	40 inches	100-200
Lumbar Spine, lateral	30 inches	200-900
Pelvis	40 inches	100-200
Skull	30 inches	100-200
Sinuses	30 inches	100-200

FIG. 141. Suggested milliampere-second values for various regions of the body.

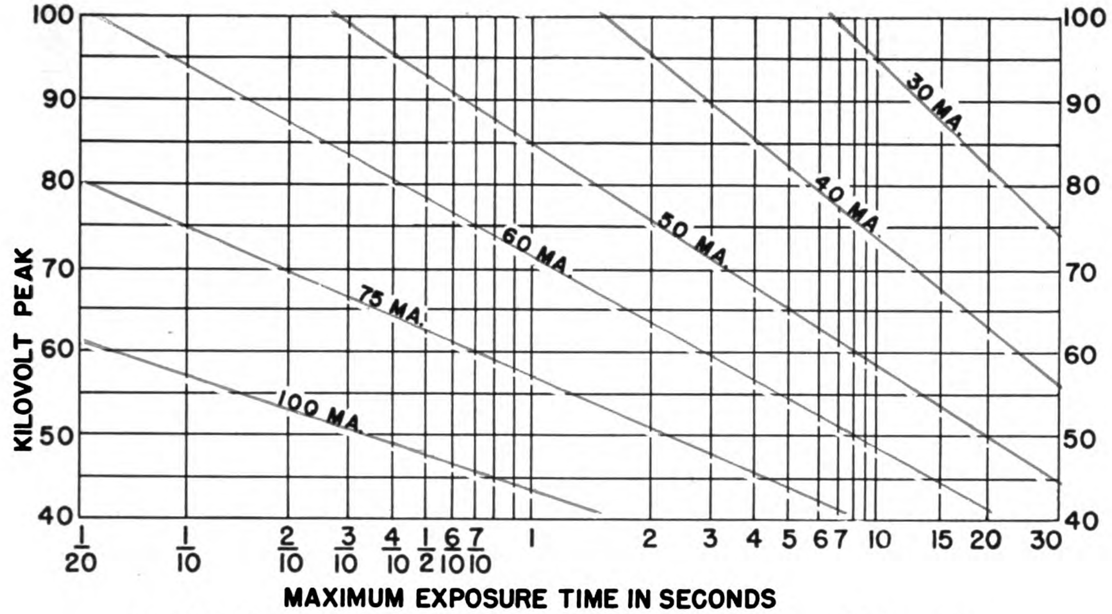

FIG. 142. Tube rating chart for 2-millimeter focal spot on a full-wave rectified generator.

Satisfactory values of milliampere-seconds must first be selected for representative areas of the body. These values are so chosen that their use establishes a tube voltage, which, at a specified distance, will produce the average degree of density and contrast. Typical values are given in the table, Figure 141.

With this information as a starting point, the next step is to select the time and tube current values which may be utilized. Rating data for the x-ray tube and energizing apparatus will provide the basic material.

Assuming that the equipment to be used is a 200-milliampere full-wave rectified machine with a maximum voltage rating of 100 kilovolts peak and that the tube is a 2-4.5 unit with a small focal spot of 2 millimeters and a large focal spot of 4.5 millimeters, we may refer to Figures 142 and 143, which are rating charts for this combination. From these charts will be found the shortest time which will give the desired milliampere-second value at the maximum voltage rating of the tube (100 kilovolts peak) using both the small and large focal spots. Whether

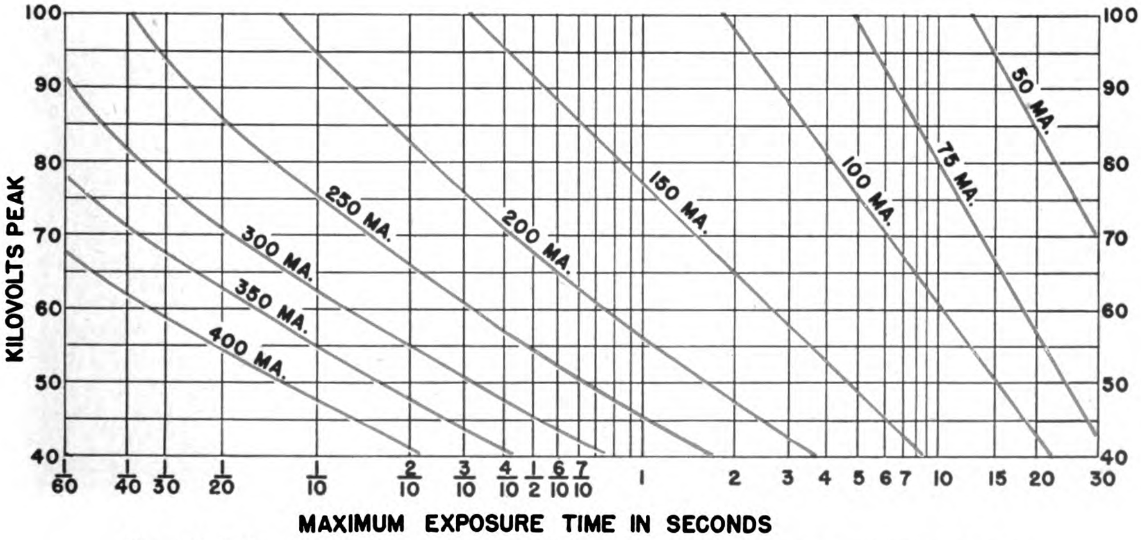

FIG. 143. Tube rating chart for a 4.5 millimeter focal spot on a full-wave rectified generator.

one or the other will ultimately be used will depend upon the kind and degree of motion present in the part which is to be radiographed, the choice of small focal spot and longer time, or large focal spot and shorter time being that which will result in the greatest detail sharpness. 100 kilovolts peak is used as the tube voltage in establishing these figures since it establishes a limit beyond which the selected technic will never be carried with the result that the tube limit will never be exceeded. Referring to Figure 142 and selecting 10 milliampere-seconds, it is found that 50 milliamperes and approximately $\frac{2}{10}$ second is the shortest time within the limits of the tube.

Referring to Figure 143 for the same approximate kilovolts peak value on the large focal spot, the following is found: 45 milliampere-seconds, 150 milliamperes, $\frac{3}{10}$ second.

The same kilovolts peak value for small and large focal spots will produce radiographs of the same density and contrast for a given part and a given milliampere-second value. The choice of one or the other is made with consideration of detail sharpness as affected by focal spot size on the one hand and motion of the part on the other. It is generally recognized that for those regions subject to involuntary motion such as the lungs, the heart, the G-I tract, and the G-U system, the shorter exposure times with the larger focal spot may give the sharpest definition in the radiograph. For those regions in which motion is voluntary and can be controlled, a longer exposure may be used with the small focal spot, as in the spine, the skull, the sinuses, etc.

From a practical viewpoint, the use of odd milliampere values, such as 35 milliamperes or 140 milliamperes, is inconvenient. The combination as obtained from rating charts is often modified in the interest of simplicity and ease of manipulation of the x-ray control equipment. Making these modifications and using the large or small focal spot where each is best fitted, the milliampere and time values in Figure 144 are listed as examples.

Region	*Focal Area*	*Milliampere-Seconds*	*Milliamperes*	*Time*
Chest	Large	10	200	1/20 second
Extremities (screen)	Large	5	100	1/20 second
Stomach	Large	100	200	1/2 second
Gall Bladder	Large	50	100	1/2 second
Colon	Large	100	100	1 second
Kidney	Large	200	100	2 seconds
Ureters	Large	200	100	2 seconds
Urinary Bladder	Large	200	100	2 seconds
Spine, antero-posterior	Small	200	20	10 seconds
Pelvis	Small	200	20	10 seconds
Skull	Small	100	20	5 seconds
Sinuses	Small	100	20	5 seconds
Lumbar Spine, lateral	Small	300	20	15 seconds

FIG. 144. Example chart based on safe tube ratings for various regions of the body.

E. Time of Exposure

X-ray output from a generator bears a linear, directly proportional relationship to the duration of the x-ray exposure. Changes in time of exposure produce corresponding proportional changes in quantity of radiation generated in the tube. That this should be so follows from an analysis of the mechanism of x-ray production.

X-rays are generated by the impact of very rapidly moving electrons on a relatively massive target. In the rearrangement of the atomic structure which is continually taking place during bombardment, an energy conversion occurs which is accompanied by the emission of x-rays from the area of electron impact. The conversion proceeds as long as electrons are accelerated across the interelectrode space within the x-ray tube. Their availability depends on the temperature and surface area of the filament; their velocity on the potential applied to the anode. The process, then, is continuous and constant if these factors are unchanged and the total quantity of radiation will be a direct function of its duration.

The effect of exposure time on film density has already been considered. The effect of exposure time on contrast is less direct than its effect on density. Defining contrast as the degree of difference in density between adjacent areas on the film, it is not difficult to recognize that gross over-exposure or under-exposure will affect this difference. If the radiograph is too dense overall, the difference in density between the

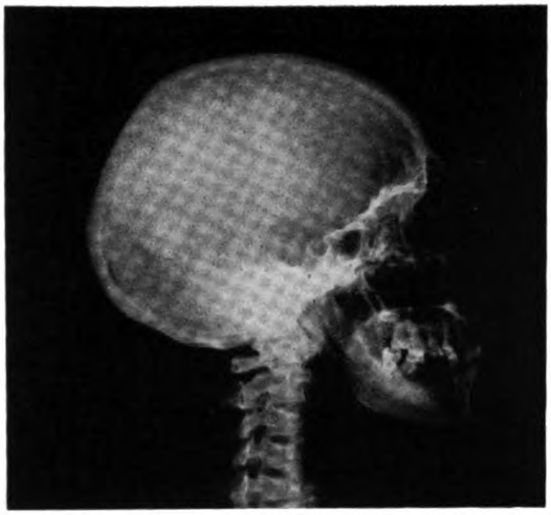

FIG. 145. Radiograph of a skull, lateral view, taken at 25 milliampere-seconds, 60 kilovolts peak.

less opaque and the more opaque areas will be diminished because the greatest density can be no more than visual black, while the least density becomes a deeper gray, approaching black as exposure time is increased. If the radiograph is excessively light, again contrast is affected because the radiographic shadow of the most opaque areas can be no lighter than the film base, while the density in the less opaque areas will be insufficiently dark. The total range is thus cut down to narrow limits, a condition indicative of inadequate contrast. Figure 145 is a radiograph of a skull, lateral, made with 25 milliampere-seconds, 60 kilovolts peak; Figure 146 is made at 50 milliampere-seconds; and Figure 147 is made at 100 milliampere-seconds, showing the differences in density obtained by successively doubling the time values.

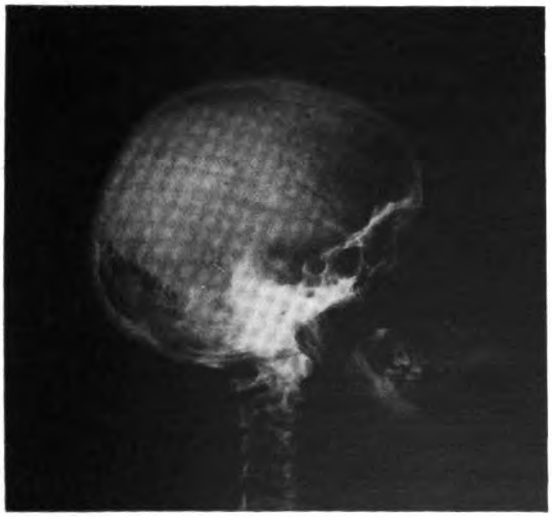

FIG. 146. Radiograph of a skull, lateral view, taken at 50 milliampere-seconds, 60 kilovolts peak.

There is a subsidiary effect of time of exposure on contrast which is of great importance technically. Since increasing exposure increases density, it is possible to compensate by a suitable reduction in tube voltage. Such reduction increases the effective wavelength of the x-ray beam and with it, the absorption differentiation in the region being radiographed. With modern high-powered x-ray apparatus, it is possible to increase contrast in this manner for many parts of the body to the point where visibility of structure may even be lost due to excessive contrast and still remain within the limits of exposure time established by the problem of motion. ***Technics should not be used to produce maximum contrast, but rather technics which will give satisfactory contrast for maximum visibility of structure.***

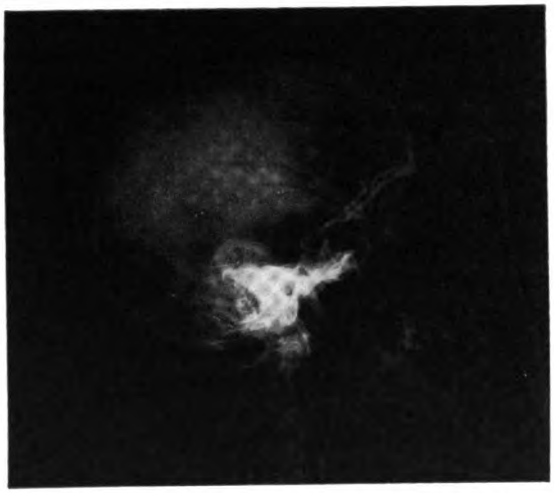

FIG. 147. Radiograph of a skull, lateral view, taken at 100 milliampere-seconds, 60 kilovolts peak.

Time of exposure cannot be used as a variable without full awareness of the limitations established by the type and degree of motion present in the particular area being radiographed. Consideration has already been given the factor of exposure time as it affects detail sharpness and its relationship to radiographic technic generally.

Another very important consideration which must be constantly kept in mind is the energy limitation of the x-ray tube as exposure time is increased. The total energy input is a linear function of time. If the time is doubled, the energy input is doubled to increase film density 100 per cent. If time is used as the only variable factor, it is entirely possible that severe and destructive overloading of the x-ray tube may result. Recognizing that many technics are based on a tube load of 50 per cent to 80 per cent of its rating, doubling the time will result in an input of 100 per cent to 160 per cent of the maximum rating. It is safe to use a 4.5 millimeter focal spot on a full-wave circuit at 150 milliamperes and 90 kilovolts peak for ½ second, but doubling the time to 1 second will result in a 25 per cent overload. There is an ever-present invitation to overloading when exposure time alone is increased to compensate for the additional thickness of heavier patients. This can be prevented by establishing an upper limit for the heaviest patient within the limit of a tube.

It is preferable to use tube voltage as a variable in controlling density, because relatively small changes produce wide changes in radiographic density. The total energy input is affected relatively little, making it possible to maintain a reasonable safety factor for the x-ray tube and for radiation to the patient.

1. Safe Exposure Limits

In considering time of exposure as a selective variable in radiographic technic, it is not enough to inquire into the effect on density, contrast, and detail sharpness. There are important limitations imposed by the safe skin tolerance of the patient and others equally serious by the thermal rating of the x-ray tube.

a. Patient

The x-ray spectrum from a tungsten target, excited by electrons under the influence of a pulsating electrostatic field, is a heterogeneous combination of assorted wavelengths, the minimum fixed by the peak electrical potential (kilovolts peak), and the maximum by the absorption characteristics of whatever material intervenes between the inside of a tube and the patient's skin. The longer wavelengths in the composite beam possess a low degree of penetrability and are absorbed in or near the proximate skin surface, producing no useful effect on the film. Because of attenuation in the tissue, however, a biological reaction may be induced, accompanied by erythema.

In x-ray therapy, these limits have been established for all the commonly used types of radiation on the basis of the effective wavelengths of the beam, and its intensity measured in roentgen units. Radiographic technics are understood in terms of tube current (milliamperes), accelerating potential (kilovolts peak), focal-film distance, and time of exposure. It is necessary, then, to formulate safe exposure limits in terms of these factors measured at diagnostic voltages.

The most convenient set of variables is tube current and time; better yet, their product, milliampere-seconds. With such a unit, the wide variation in technics for the various parts of the body can be reduced and easily computed in terms of two factors which are always known. There are, however, two difficulties which are introduced at once. First, the accelerating potential (kilovolts peak) is also a variable in radiographic procedures and x-ray output is markedly affected by its variation. Second, safe exposure limits vary with the wavelength of radiation, which in turn is the function of tube voltage. The distance from the x-ray source to the skin is another factor of importance. The tube may be as close as 8 inches from the skin when radiographing the mastoids, or as far as 64 inches in chest work. The inverse-square law is a satisfactory expression of a variation in intensity with distance and can safely be used, the only *caution* being that the focal-skin distance and not the focal-film distance is the basis for measurement.

The effect of filtration must also be considered. Since the radiation at the long wavelength end of the spectrum is that which is particularly damaging at the skin surface, its removal from the composite beam by filtration through a metallic absorber such as aluminum will naturally increase the permissible milliampere-second quantity. As the filter thickness is increased from ¼ millimeter to ½ millimeter, and from ½ millimeter to 1 millimeter of aluminum, more and more of the longer wavelengths are subtracted, increasing the safe exposure limits. The shockproof x-ray tube casings which are commonly used today are of necessity so constructed that the x-ray beam must pass through oil and

Target-Skin Distance Inches	*Filter (Millimeters Aluminum)* *External—None* *Inherent—0.5* *Total —0.5*	*Filter (Millimeters Aluminum)* *External—0.5* *Inherent—0.5* *Total —1.0*	*Filter (Millimeters Aluminum)* *External—1.0* *Inherent—0.5* *Total —1.5*
10	265 milliampere-seconds	510 milliampere-seconds	810 milliampere-seconds
12	380 milliampere-seconds	730 milliampere-seconds	1090 milliampere-seconds
14	520 milliampere-seconds	1000 milliampere-seconds	1500 milliampere-seconds
16	680 milliampere-seconds	1300 milliampere-seconds	1950 milliampere-seconds
18	870 milliampere-seconds	1650 milliampere-seconds	2500 milliampere-seconds
20	1060 milliampere-seconds	2050 milliampere-seconds	3000 milliampere-seconds
22	1280 milliampere-seconds	2450 milliampere-seconds	3640 milliampere-seconds
24	1530 milliampere-seconds	2900 milliampere-seconds	4360 milliampere-seconds
30	2400 milliampere-seconds	4500 milliampere-seconds	6800 milliampere-seconds
36	3460 milliampere-seconds	6500 milliampere-seconds	9800 milliampere-seconds
42	4700 milliampere-seconds	8850 milliampere-seconds	13300 milliampere-seconds
48	6150 milliampere-seconds	11600 milliampere-seconds	17400 milliampere-seconds

FIG. 148. Maximum permissible exposure values for all parts of the body excepting the head, 85 kilovolts peak.

bakelite or similar materials. The absorption characteristics of these materials, though not the same as aluminum, produce much the same effect. The equivalent filtration of such casings is usually expressed in terms of aluminum, and this information can be obtained from the manufacturer. The range of variation in filtration for different types of tube units is from the equivalent of 0.25 millimeter of aluminum to the equivalent of 0.75 millimeter of aluminum; the average inherent filtration being 0.5.

In the tables, Figures 148 and 149, are given a compilation of safe exposure values. These tables apply to both radiography and fluoroscopy and are based on 85 kilovolts peak. When using higher kilovoltage, a reduced value must be used.

For adjustment of these tables, when using a kilovoltage different from 85 kilovolts peak, the percentage changes in Figure 150 may be used.

The first table applies to all parts of the body excepting the head; the second to the head only, and is a reduction of approximately 25 per cent of the values of the first.

b. X-Ray Protection for the Operator

The following is quoted from *International Recommendations for X-Ray and Radium Protection,* revised by the International X-Ray and

Target-Skin Distance Inches	*Filter (Millimeters Aluminum)* *External—None* *Inherent—0.5* *Total —0.5*	*Filter (Millimeters Aluminum)* *External—0.5* *Inherent—0.5* *Total —1.0*	*Filter (Millimeters Aluminum)* *External—1.0* *Inherent—0.5* *Total —1.5*
10	200 milliampere-seconds	380 milliampere-seconds	610 milliampere-seconds
12	290 milliampere-seconds	550 milliampere-seconds	875 milliampere-seconds
14	390 milliampere-seconds	750 milliampere-seconds	1190 milliampere-seconds
16	510 milliampere-seconds	970 milliampere-seconds	1560 milliampere-seconds
18	650 milliampere-seconds	1240 milliampere-seconds	1980 milliampere-seconds
20	800 milliampere-seconds	1530 milliampere-seconds	2450 milliampere-seconds
22	960 milliampere-seconds	1840 milliampere-seconds	2970 milliampere-seconds
24	1150 milliampere-seconds	2150 milliampere-seconds	3540 milliampere-seconds
30	1790 milliampere-seconds	3360 milliampere-seconds	5540 milliampere-seconds
36	2585 milliampere-seconds	4840 milliampere-seconds	7950 milliampere-seconds
42	3600 milliampere-seconds	6560 milliampere-seconds	10850 milliampere-seconds
48	4600 milliampere-seconds	8500 milliampere-seconds	14100 milliampere-seconds

FIG. 149. Maximum permissible exposure values for the head, 85 kilovolts peak.

Kilovolts	*Change in Maximum Permissible Exposure Values*
100	Reduce by 25%
90	Reduce by 8%
85	No change
80	Increase by 10%
70	Increase by 35%
60	Increase by 80%

FIG. 150. Variation in maximum permissible exposure values with kilovoltage employed.

Radium Protection Commission at the Fifth International Congress of Radiology, Chicago. September, 1937. (Note: These recommendations were completely published in RADIOLOGY, Vol. 30, No. 4, p. 511, April, 1938.)

"I. *International Recommendations*

"1. The dangers of over-exposure to x-rays and radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of x-ray and radium departments to ensure such conditions for their personnel. The known effects to be guarded against are:
  a. Injuries to the superficial tissues.
  b. Changes in the blood and derangements of internal organs, particularly the generative organs.

"The evidence at present available appears to suggest that under satisfactory working conditions, a person in normal health can tolerate exposure to x-rays or radium gamma rays to an extent of about 0.2 international roentgens (*r*) per day, or 1 *r* per week. On the basis of continuous irradiation during a working day of seven hours, this figure corresponds to a tolerance dosage of 10^{-5} *r* per second. The protective values given in these recommendations are generally in harmony with this figure under average conditions.

"III. *X-Ray Protective Recommendations*

"10. An x-ray operator should on no account expose himself to a direct beam of x-rays.

"11. An operator should place himself as remote as practicable from the x-ray tube. It should be borne in mind that valve tubes are capable of producing x-rays.

"12. The x-ray tube should be self-protected, or otherwise surrounded as completely as possible, with protective material of adequate lead equivalent.*

"13. The following lead equivalents are recommended under average conditions:

X-rays generated by peak voltages	*Minimum equivalent thickness of lead*
Not exceeding 75 kv	1 mm
100	1.5
125	2
150	2.5
175	3
200	4
250	6
300	9
350	12
400	15
(600)	(35)

---

* The lead equivalent of a given thickness of protective material is that thickness of lead which is equally opaque to x-rays excited at some specified peak voltage."

The objective sought by the position, type, and amount of protective material which should be used for a given installation is to limit the amount of radiation reaching a given location to not more than that quantity which "corresponds to a tolerance dosage of 10^{-5} *r* per second."

For such reasons as distance from the primary emitting source, material used in the building structure, location of others with respect to the primary beam, equipment construction and inherent filtration, the thickness of protective material required to provide adequate protection to all may for some locations be less than shown in the above table.

The essential requirement is not the thickness nor the type of protective material used, but rather that it shall be used in such quantities and locations as to prevent any individual from being subjected to a dosage rate in excess of 10^{-5} *r* per second.

c. Tube Heat Storage Capacity

Mention has been made of the energy limitation of the x-ray tube as an important consideration in the use of time of exposure as a variable factor in radiographic technic. It was pointed out that the total energy input and output are linear functions with time and that any increase in the quantity of x-ray delivered by the tube must be produced by a proportional increase in energy input, if duration of exposure is the sole variable. Tube voltage is recommended in controlling density because relatively small changes produce considerable effect on radiographic density.

With what has already been written about tube ratings and focal areas, it should be evident that changes in exposure time are to be made with caution and only after reference to the tube rating chart. If the energy limitation of the focal area for a single exposure is exceeded, melting of the target may result.

There is another limitation which is equally important from the standpoint of tube life and is of interest in the investigation of time of exposure as a factor in the production of the radiograph. This is the thermal rating of the tube, based on heat capacity and rate of heat dissipation. This rating determines the frequency with which exposures may be made and the time intervals which must be allowed between exposures for the dissipation of heat from the anode of the tube. A not uncommon cause of tube failure is excessive heat input beyond the capacity of the anode to absorb and dissipate such energy. It is quite possible to make a series of exposures, each within the limits of the tube rating chart, but so great in number that the temperature of the anode, apart from the focal area, may be raised to a point sufficiently high to melt some portion of it.

Since it is not convenient to measure the anode temperature directly, the heat rating of the tube must be based on the energy input. With this information on the rate of heat loss, the limits of operation in terms of tube current (milliamperes), tube voltage (kilovolts peak), and time for each exposure, the number of exposures, and the time interval between successive series of exposures may be established.

An arbitrary heat unit of kilovolts peak times milliampere-seconds is used, and forms the basis for the calculation of thermal ratings. For example, a radiograph of the antero-posterior view of the pelvis may be made using

60 kilovolts peak, 20 milliamperes, 5 seconds (100 milliampere-seconds)

The heat input would then be

$$60 \times 20 \times 5 = 6{,}000 \text{ heat units}$$

If a series of radiographs were to be made of the antero-posterior pelvis (stereo), antero-posterior lumbar spine, antero-posterior dorsal spine, lateral lumbar spine, and lateral dorsal spine, the total heat input would be calculated as follows:

Antero-posterior pelvis (stereo)

2 × 60 kilovolts peak × 20 milliamperes × 5 seconds = 12,000 heat units

Antero-posterior lumbar spine

64 kilovolts peak × 20 milliamperes × 5 seconds = 6,400 heat units

Antero-posterior dorsal spine

68 kilovolts peak × 20 milliamperes × 5 seconds = 6,800 heat units

Lateral lumbar spine

70 kilovolts peak × 20 milliamperes × 10 seconds = 14,000 heat units

Lateral dorsal spine

68 kilovolts peak × 20 milliamperes × 5 seconds = 6,800 heat units

Total = 46,000 heat units

The total heat input to the tube is then 46,000 heat units.

The cooling curves for a 2-4.5 double focus tube, an oil-immersed shockproof unit, are shown in Figure 34.

It is seen that the total maximum heat storage is 250,000 heat units. The cooling proceeds logarithmically, the rate of loss being a function of the total heat remaining at any time. Thus, the tube cools 50,000 heat units in the first two minutes, 35,000 in the next two, 30,000 in the next two, then 25,000, and so on, until in the last two minutes there is a loss of only 2,000 heat units. Assume now that, due to previous exposures, the input to the tube has been brought up to 225,000 heat units and it is desired to proceed with the above described pelvis and spine series. An additional 46,000 units would exceed the capacity of the tube by 21,000 heat units. It is necessary, then, to allow the dissipation of 21,000 heat units before proceeding. Examination of the curve starting at 25,000 indicates that one minute would be an interval sufficiently long for the cooling to take place. At the end of this time, the total heat storage would be 200,000 heat units, and the contemplated 46,000 in addition would not exceed 250,000.

Using such a tube, no practical inconvenience nor loss of time would be experienced because the removal of one patient and the preparation of the next would require more than one minute. This type of tube, due to its design and oil-immersion, has a relatively high thermal rating and is recommended.

Consider next the use of an air-cooled radiator, bulb-type tube, the cooling curves for which are shown in Figure 151:

It is seen that the maximum capacity is 100,000 heat units in comparison to 250,000, Figure 34, and the rate of heat loss is such that 100,000 heat units are dissipated in 30 minutes. In the first two minutes the tube loses 20,000 heat units; in the next two, 15,000 heat units, in the next two, 12,000 heat units, etc. In comparison to the oil-immersed tube, the rate of heat loss is appreciably less. If the same series of exposures totalling 46,000 heat units were applied to this type of tube which had previously been loaded to some value slightly under the maximum limit, 90,000 units for example, it would be necessary to allow the dissipation of 36,000 heat units. Reference to the curve starting at 90,000 units indicates that a time interval of five minutes is necessary before proceeding with the radiographs.

Thermal capacity and rate of cooling are determined by tube design and the method of cooling. From the figures obtained for two representative types, the oil-immersed and radiator tubes, there is clearly a difference in the number of exposures which may be made by each during the course of a working day. Despite the initial cost of the oil-immersed type, it is the more economical one where a considerable amount of work is being handled.

F. Focal-Film Distance

The effect of focal-film distance on detail sharpness or definition was considered in Chapter VI.

Focal-film distance within itself has no effect

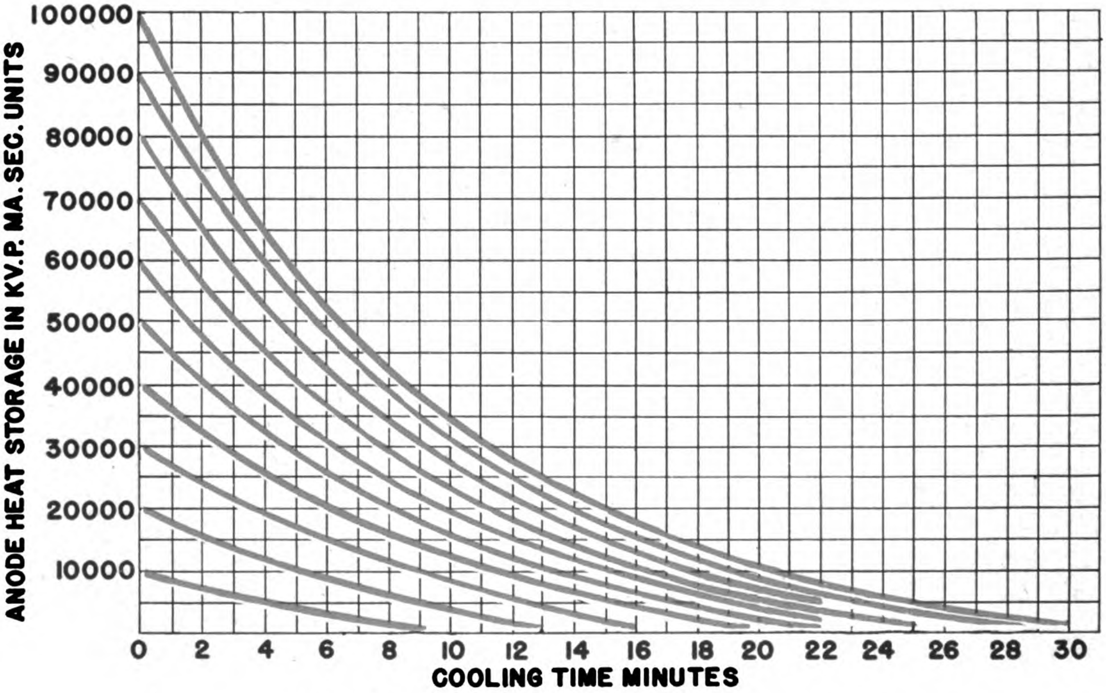

FIG. 151. Cooling curve for an air-cooled bulb type tube.

upon radiographic contrast. However, a variation in focal-film distance affects radiographic density appreciably. Of the four principal factors, focal-film distance usually receives the least consideration. When it is necessary to tilt the tube for certain areas, it is not uncommon for the operator to read the distance on the tube column scale just as though the tube were not tilted. In some instances this may mean an error of 10 to 20 per cent in focal-film distance.

However, radiographic density varies inversely as the square of the distance, with the result that what may appear to be only a small change in focal-film distance represents a substantial change in film density. The difference in film density with a change in focal-film distance from 30 inches to 36 inches would be approximately 40 per cent.

Because of magnification and detail changes with a variation in focal-film distance, this factor should not be used as a means for changing density except in extreme cases.

G. Secondary Radiation

The effect of secondary radiation on density and contrast in the radiograph is a problem that must be considered.

It is necessary first to describe some general characteristics of x-radiation and the origin of secondary rays. The mechanics of x-ray generation have been described. The impact of high speed electrons against a metallic target results in emission of x-rays from the surface of bombardment. These rays, called primary rays, are composed of a type of radiation characteristic of the target material together with a heterogeneous mixture of wavelengths, the limit of which is fixed by the maximum electron velocity in the cathode stream.

When the x-ray beam described is allowed to fall on and pass through any physical substance, certain changes take place in radiation accompanied by a partial conversion in its form.

As a result of the interaction of the primary beam on the absorbing material, secondary radiation results. While secondary radiation may be broken down into several components, there are two which are generally considered in radiography:

1. Scattered radiation
2. Characteristic radiation

One of these is similar in nature to the primary beam, differing only by a shift in wavelength and is referred to as scattered radiation. The other is a function of the atomic number of the absorbing material and is referred to as characteristic radiation.

We consider each unit volume of the substance in the path of the primary beam to be in itself a source of photo-active radiation, emitted in all directions and effective, like the primary source, in darkening the x-ray film. In order to examine the radiographic effect, the picture can be simplified by considering the primary radiation as a single rectilinear form proceeding from the focal area, and the scattered and secondary radiations together as another single form, propagated in all directions from the radiated mass, Figure 152.

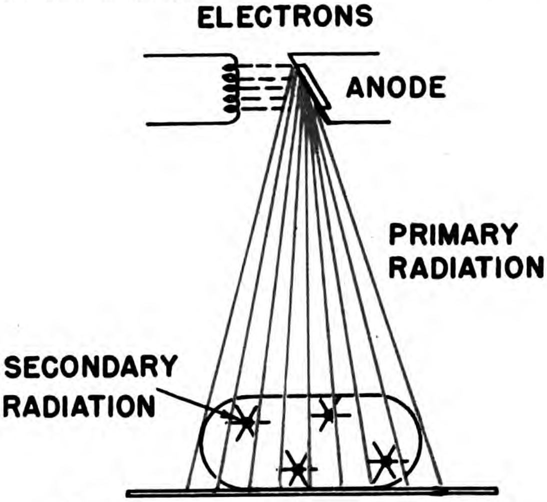

FIG. 152. Composition of primary beam.

From this diagram it can be seen that the effect of radiation from sources other than the focal area is to produce a diffusion of the image by obscuring the lighter portions of the radiograph. The contrast, or difference in density, between adjacent film areas, is materially reduced, and the gradations of density become less visible throughout the entire film. Secondary radiation reduces the differentiation of intervening structures upon which the quality of the radiograph depends. The degree of secondary effect is controlled by the following factors:

1. Opacity of radiated material.
2. Volume of radiated material.
3. Quantity and quality of primary radiation.

The first two of these determine the x-ray opacity of the part being examined, and this in turn establishes the third, so that the heavier parts offer the greatest difficulty in loss of contrast due to secondary radiation. Without some method for limiting such effects, it would be quite impossible to produce radiographs of the highest quality in such areas as the lumbar or dorsal spine, the pelvis, the gall bladder, etc. Even where a considerable quantity of opaque material is used in the gastro-intestinal tract, unscreened secondary radiation produces objectionable fog in the x-ray film for all but the thinnest patients.

1. Cones and Diaphragms

Analyzing these factors, it is evident that the first is a characteristic of the patient and, except by compression, or displacement, cannot be controlled. The third is determined by the desired degree of radiographic density and contrast and by the opacity of the region. The second factor, however, can be further examined for the possibilities of manipulation.

If the total irradiated field be kept to the smallest possible area for any desired region of the body, then the quantity of secondary radiation will be reduced in approximate proportion to the square of the field diameter.

In radiographing the gall bladder, for example, the circle of radiation, if no special devices are used, may be 12 inches in diameter or more. Assuming the patient to measure 9 inches in thickness, the irradiated volume would be 1000 cubic inches. If the circle of radiation could be limited to 4 inches in diameter, the irradiated volume would be 110 cubic inches and the quantity of secondary radiation would be substantially reduced.

Thus the restriction of the x-ray beam to small areas should prove advantageous, particularly for those regions of considerable thickness and opacity such as the abdomen, the skull, the knee, the shoulder, etc.

In practice this prediction is verified by definite improvement in contrast with limitation of the port of entry of the x-ray beam. In radiography of the sinuses, mastoids, gall bladder, kidneys, bladder, and lumbar spine, we have examples of areas in which the region of diagnostic interest is surrounded by tissue which acts as a source of secondary radiation. By cutting down the field area, the fogging effect of these rays is limited. Figure 153 is a radiograph of a shoulder made with a 3-inch cone, but with no other device for eliminating secondary radiation. Figure 154 is a radiograph taken with no cone.

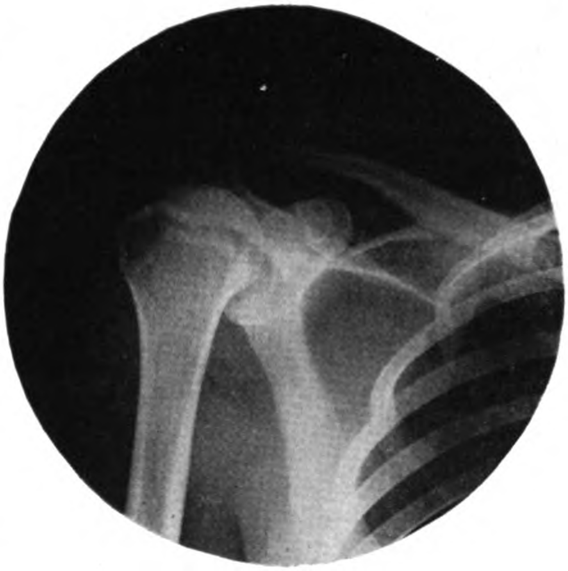

FIG. 153. Radiograph of a shoulder made with a 3-inch cone.

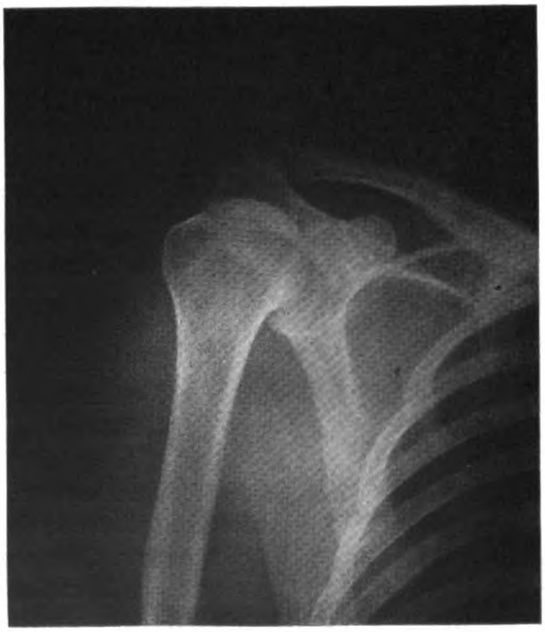

FIG. 154. Radiograph of a shoulder made without cone, all other factors remaining constant.

The many mechanical devices available for field limitation (limiting the port of entry) can be classified as cones, cylinders, and diaphragms. Cones are, as the name designates, tapered metal structures available in a variety of lengths and diameters for fitting to the tube port. Telescopic cylinders are of a shape which permit variation in length as the sections are contracted or expanded. They are, in effect, adjustable cones which can be used as immobilizing devices in contact with the body. The diaphragms are used close to the tube, often inserted into the filter slide, or in the form of sheet lead or leaded rubber with suitable apertures placed on the patient's body.

To intelligently use cones, cylinders, and diaphragms, it is necessary to know the size of field which will be covered at the various distances employed. A cone with a small aperture used at a long distance will be no more effective in controlling secondary radiation than a larger cone used closer to the film.

A cone with a small aperture at a close distance may not cover the desired area while, at the other extreme, it may be so large that the portion of the body falling outside the cone circle is relatively insignificant, in which case the cone is of little value.

In the radiography of the wrist, elbow, or ankle, for example, if the entire area is to be included, the field outside the region of interest has very little effect as a source of secondary radiation.

The accompanying illustrations show the variety of cones and cylinders available for radiographic use, those in Figure 155 attaching to the x-ray tube stand, and those in Figure 156 fitting directly to the shockproof tube casing. To the right in each illustration is an extension cylinder, a device which combines the separate utilities of a cone and an immobilizing device.

The use of such attachments requires some information concerning the size of field which will be covered at various focal-film distances.

Preliminary to such calculations, the following data is necessary:

1. Large diameter of cone (d)
2. Length of cone (l)
3. Distance from small end of cone to tube focal spot (z)
4. Focal-film distance (L)

With these measurements the field diameter at the film surface (D) can be computed with the following formula:

$$D = \frac{L}{l + z} \times d$$

If the film is to be entirely covered, the diameter D must be equal to or greater than the film diagonal which can readily be calculated with the following:

$$c^2 = a^2 + b^2$$

in which c = film diagonal
a = film width
b = film length

As an example, we will calculate the size of field and film for the type E cone, Figure 155, for which the end diameter is 5 inches and the length is 8 inches. The cone will be attached to the tube stand on which is supported a shock-

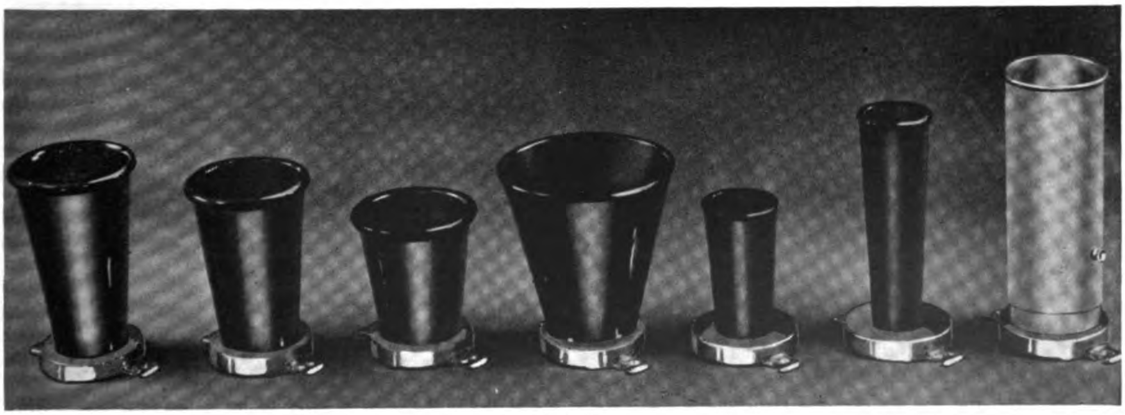

FIG. 155. Representative cones and cylinders available for attachment to the x-ray tube stand.

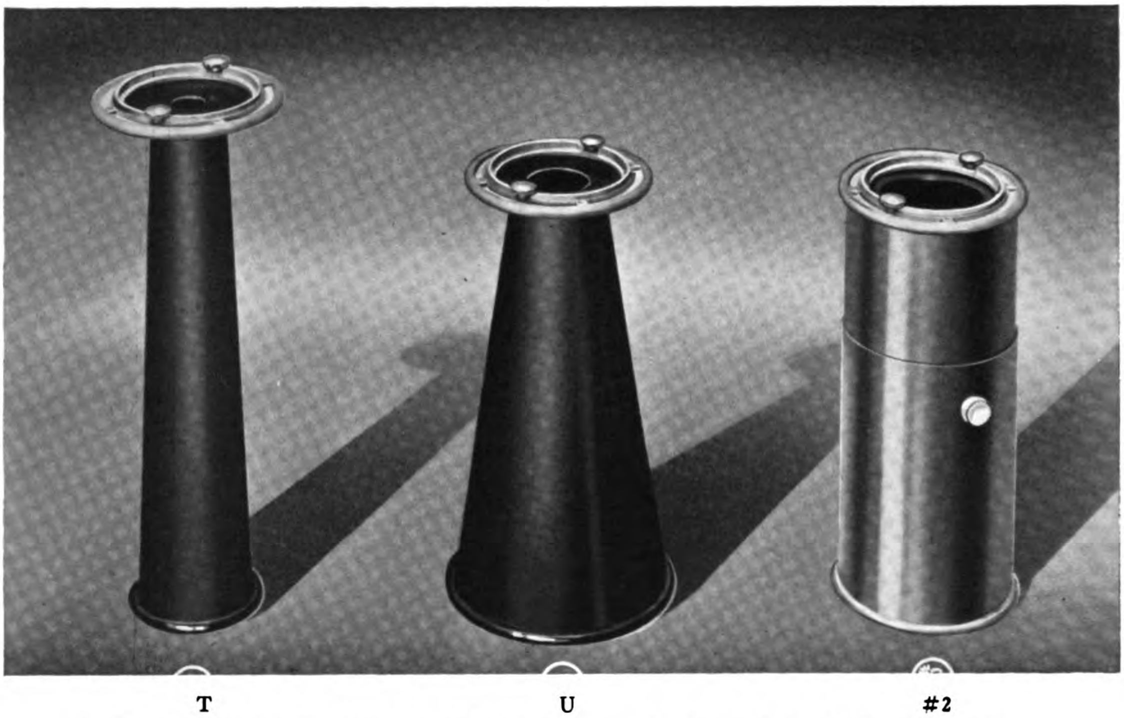

FIG. 156. Cones and cylinders available for attachment directly to the shockproof tube casing.

proof casing of such size that the distance from the focal spot to the small end of the cone is 5 inches. This will, of course, depend on the size and form of the casing, lead glass bowl, or x-ray protective cover. Finally, let the focal-film distance be 36 inches. Then, in the first formula,

$$\begin{aligned} L &= 36 \text{ inches} \\ l &= 8 \text{ inches} \\ d &= 5 \text{ inches} \\ z &= 5 \text{ inches} \end{aligned}$$

$$D = \frac{36}{8 + 5} \times 5 = 13.8 \text{ inches.}$$

The next step is to determine the standard film size, the diagonal of which is equal to or less than 13.8 inches. Knowing that the film length must be less than this figure, no consideration need be given to the 14 by 17 inch or the 11 by 14 inch sizes. Using the second formula and the values for a 10 by 12 inch film,

$$\begin{aligned} a &= 10 \text{ inches} \\ b &= 12 \text{ inches} \end{aligned}$$

$$c = \sqrt{10^2 + 12^2} = 244 = 15.6 \text{ inches}$$

In this case the diagonal is greater than the field diameter by 1.8 inches, which means that approximately 1 inch would be cut off at the corners of the film. From a practical standpoint this would hardly be objectionable though, for complete coverage, the 8 by 10 inch film would be the limit. The data are tabulated in Figure 157.

2. Applications of Cones and Diaphragms

a. The Head

In radiography of the skull and its contents, cones are of great value when the areas of diagnostic interest are small in comparison to the head in its entirety. The need for cones becomes imperative when, due to position or tube angulation, the Potter-Bucky diaphragm cannot be used. In such cases, by minimizing secondary radiation, the cone serves in part the function of the bucky grid.

(1) *Sinuses.* For the postero-anterior projection of the nasal accessory sinuses, extension cylinders No. 1 and No. 2 are particularly useful since they combine the functions of a cone and an immobilizing device. Cones D or T can also be used effectively as they project circles over 5 inches in diameter at a 30-inch focal-film distance. This area is large enough to include the

Cone	*d*	*l*	*z*	*L*	*D*	*Film*
A	5	6⅜	5	30	13.2	8x10
				36	15.8	10x12
				40	17.6	11x14
B	8	8	5	30	18.5	11x14
				36	22.2	14x17
				40	24.6	14x17
C	5	9½	5	30	10.4	8x10
				36	12.4	8x10
				40	13.8	8x10
D	3¼	11½	5	30	5.9	
				36	7.1	5x7
				40	7.8	5x7
E	5	8	5	30	11.6	8x10
				36	13.8	8x10
				40	15.4	10x12
F	3	6½	5	30	7.6	5x7
				36	9.4	5x7
				40	10.4	8x10
Ext. Cylinder #1						
(collapsed)	4	10	5	30	8	5x7
				36	9.6	5x7
				40	10.6	8x10
(extended)	4	18	5	30	5.2	
				36	6.3	
				40	7.0	5x7
T	2¾	12	3	30	5.5	
				36	6.6	
				40	7.3	5x7
U	5¼	10	3	30	12.1	8x10
				36	14.6	10x12
				40	16.1	10x12
Ext. Cylinder #2						
(collapsed)	4	6½	3	30	12.6	8x10
				36	15.2	10x12
				40	16.9	11x14
(extended)	4	12	3	30	8.0	5x7
				36	9.6	5x7
				40	10.6	8x10

FIG. 157. Film coverage and size of field for various types of cones and cylinders.

sinus regions in the various projections. For the lateral view, these same devices can be used.

(2) *Mastoid.* Cones D or T, when used at distances from 20 to 30 inches, will cover a circle over 3 inches in diameter. Cylinders Nos. 1 and 2 are excellent for this application, producing larger fields which permit reasonable latitude in centering without danger of insufficient coverage.

(3) *Skull.* For the antero-posterior, postero-anterior, and lateral views, Cones C or U are of value. The extension cylinders are also quite useful, particularly where the areas of interest are less than the entire skull, as in the occipital and foramen magnum projections. For the sella turcica, the optic foramen, and the zygomatic arch, Cones D, F, or T may be used with advantageous effect.

(4) *Teeth.* Cones D, F, or T are of particular value in radiography of the teeth when the regular medical x-ray equipment is employed. In this application the cone is also an important aid to centering the x-ray beam.

b. Pelvis and Spine

In radiography of the pelvis and spine, secondary radiation is particularly troublesome. This is due to the size of the area involved and its great opacity. Because of this, the Potter-Bucky diaphragm or stationary grid is used whenever available. In addition, cones assist materially in improving contrast where the field can be confined.

(1) *Pelvis.* For the entire pelvis, covering a 14 by 17 inch film, Cone B can be used at a focal-film distance of 36 inches or greater. If a smaller area is to be covered, as the head of the femur, sacro-iliac joint, or the ischium, Cones A, C, or U are quite satisfactory.

(2) *Lumbar Spine.* Cones A, E, or U will cover the entire lumber area at 36 inches, and will assist materially in improving the quality of the radiograph. In the heavier patients, the use of one of these cones is of special value. For the coccyx, antero-posterior or lateral, a smaller cone can be used, such as D, T, or the extension cylinder.

(3) *Dorsal Spine.* Cone B will include the entire dorsal spine at 30 inches, but if less inclusive areas can be permitted, improved results will be obtained with Cones A, C, E, or U.

(4) *Cervical Spine.* For the antero-posterior view, Cones A, C, E, U, or the extension cylinder are satisfactory. In radiographing the lateral projection, 60 to 72 inches focal-film distance is usually employed so that Cones D, T, or F will cover the desired area. The upper two cervical vertebrae, projected through the open mouth in the antero-posterior position, can easily be radiographed using Cone F which, because it is but 6½ inches in length, permits a short focal-film distance.

c. The Internal Organs

(1) *Gastro-Intestinal Tract.* Cones A, C, E, or U are quite helpful in radiography of the esophagus and stomach, though the latter three will not completely cover a 10 by 12 inch film at 30-inch focal-film distance. For the colon, Cone B can be employed.

(2) *Gall Bladder.* The use of a small cone in radiography of the gall bladder is a necessity if best results are to be obtained. The extension cylinder or Cone C will include an 8-inch film circle at 30 inches so that there is no danger of cutting the area with too small a field. If one film can be taken to localize the gall bladder, a second, of greatly improved quality, may be made using an even smaller cone, such as F.

(3) *Genito-Urinary System.* Cones in conjunction with compression bladders are of importance in this work. Cones A, B, C, E, and U may be used for areas which normally cover an 8 by 10 inch or 10 by 12 inch film. Cone B must be used where a greater field is desired.

(4) *The Lungs.* An increase in contrast is obtained on moderately heavy patients if secondary radiation is reduced. For these heavier individuals, there is some advantage in employing a cone of such size that it will cover a 14 by 17 inch film at 72 inches without "cut-off." Cone F or extension cylinder No. 1, fully collapsed, will serve this purpose. Lacking one of these, a rectangular diaphragm may be cut from sheet lead, 1/16 inch thick, and inserted in the filter slide adjacent to the x-ray tube. The dimensions of the opening depend on the distance from the diaphragm to the focal spot of the tube, but in most cases an aperture ⅞ inch by 1⅛ inch will be approximately correct.

d. Extremities

The use of cones in radiography of the extremities offers little advantage except perhaps as an aid in centering. These regions are not of great opacity so that the quantity of secondary radiation resulting is not disturbing. The exceptions are the knee and shoulder areas where, if the individual is heavy, or the parts are in a cast, some improvement may be effected by limiting the field of radiation.

When using cones in stereoscopy, which involves a tube shift, it must be borne in mind that the tube must also be tilted to cover the size areas described. See Chapter IX: "Stereoscopy."

3. The Stationary Grid

The purpose of the stationary grid is to reduce the amount of secondary radiation emanating from the patient, which, if permitted to strike the film, would produce objectionable secondary fog.

The bucky grid is a mechanical device composed of strips of material opaque to x-ray, separated by translucent strips assembled in wafer form and interposed between the object being radiographed and the front of the film holder. Figure 158 shows such an assembly. It is seen that in the plane of the section represented in the diagram, radiation proceeding from within the body is intercepted by the highly opaque strips while the rays which are incident to the grid face, at or near the perpendicular, pass through the relatively transparent separations. The grid, so used, will not completely eliminate secondary radiation, its effectiveness being determined by its ratio.

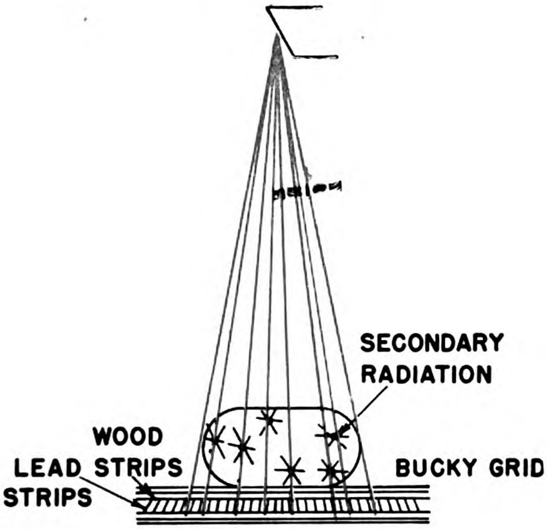

FIG. 158. Simplified section of a stationary grid.

An approximate quantitative measure of the efficiency of a grid can be obtained by determining this ratio of the thickness of the grid to the space between the opaque strips. If, for example, the thickness of the grid is 1/10 inch and the space between the opaque strips is 1/50 inch, the "ratio" of the grid is 5 to 1.

Such a grid would be more effective in eliminating secondary radiation than one in which the spacing of the opaque strips is 1/25 inch. The ratio in this case is 2½ to 1.

When the stationary grid is employed, grid shadows will appear on the film. With a modern stationary grid, however, having approximately 60 strips per inch, it is difficult to recognize their presence at a viewing distance of approximately 30 inches. At shorter distances they are, of course, evident.

In the diagram, Figure 158, the opaque elements are shown converging to a point, the focal spot of the x-ray tube. Such construction, though complex, is a modern refinement which assures uniformity of absorption in the grid from edge to edge at the radial distance. If the lead strips were perpendicular to the grid surface, there would be an increase in absorption at the edges which is especially pronounced at short focal-film distances.

The field of application for the stationary grid is the radiography or fluoroscopy of those regions of the body which are sufficiently heavy to produce objectionable secondary radiation and for which the Potter-Bucky diaphragm cannot conveniently be used. As examples:

1. Mobile or portable work for examination of the pelvis, spine, knee, shoulder, and neck of femur, etc.
2. Chest radiography, particularly where considerable secondary radiation may be caused by some pathological conditions.
3. Fluorography, or "spot-film" procedures in which radiographs of the gastro-intestinal tract are taken at intervals during fluoroscopy.

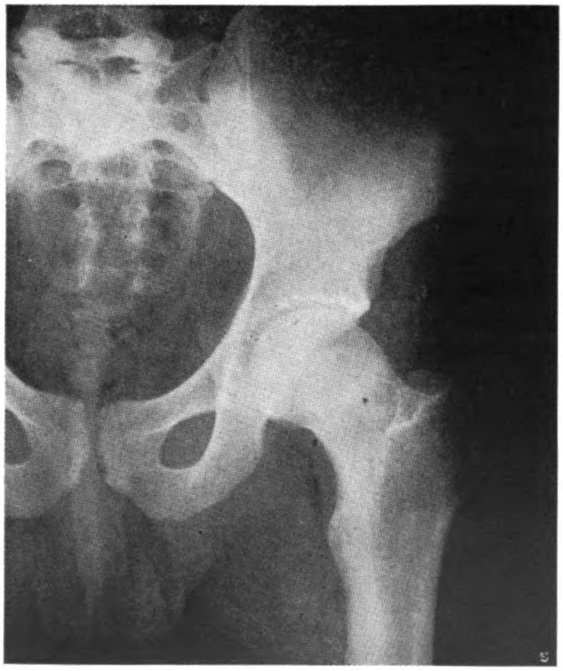

FIG. 159. Radiograph of the femoral head, taken with a stationary grid.

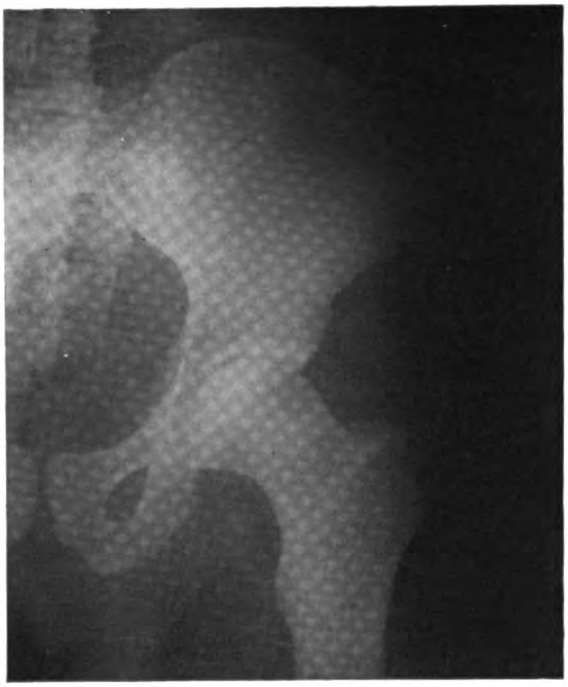

FIG. 160. Radiograph of the femoral head, taken without a grid, 13 kilovolts peak reduction.

4. Fluoroscopy, where greatly increased contrast is obtained by placing the grid directly behind the fluorescent screen.

Figure 159 is a radiograph of the head of the femur, antero-posterior, made with a stationary grid; Figure 160 is a radiograph taken without any means for eliminating secondary radiation. The compensation for grid absorption is approximately 13 kilovolts peak, all other factors remaining constant.

Because of the absorption of secondary and a certain amount of primary radiation, it is necessary to increase the x-ray energy when a stationary grid is used. For example, an increase of approximately three times in milliampere-seconds, or an addition of 13 kilovolts peak above the value required to obtain a given density without the grid.

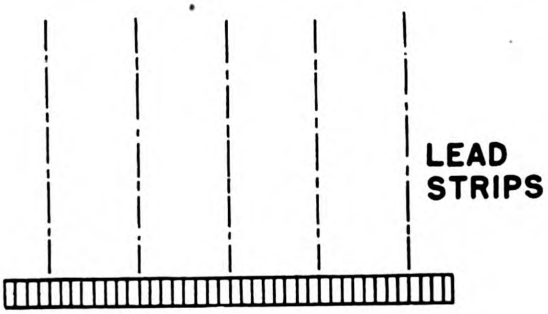

FIG. 161. Section of an unfocused grid.

Another element of grid design which must be considered is the angularity of opaque strips with respect to its surface. If the strips are perpendicular, the grid is said to be of the "unfocused" type; if they are arranged so that their projections converge at a point, the grid is said to have a radius or focus equal to the distance from this point to the grid face. Figure 161 is a section of an unfocused grid; Figure 162 is a section of a focused grid of radius "F". It is evident that an unfocused grid used at short focal-film distances will absorb much more radiation near its lateral edges than it will in the center. As a result there will be a decrease in density toward the two film edges parallel to the direction of the grid strips. This same effect will be observed but to a lesser extent on a focused grid, particularly when a focal-film distance other than the grid radius is employed.

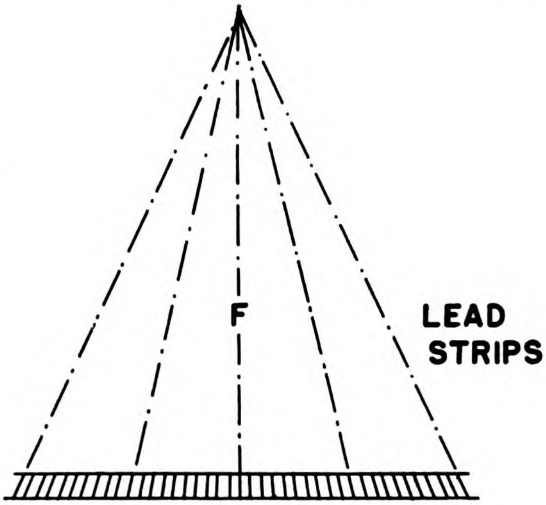

FIG. 162. Section of a focused grid of radius "F."

It is important for both the focused and unfocused grid that the tube be perpendicular to the grid. If the grid is tilted from this perpendicular, the radiation is angulated through the opaque strips rather than through the relatively transparent separating members, and may result in a film all or partially blank. Tube tilts parallel to the direction of the strips are quite permissible and produce no objectionable variations in density. It is important that this be kept in mind in bedside or mobile applications where a great variety of angulations and variations in position may cause one to overlook the direction of the grid strips.

Another condition which must be observed is the centering of the x-ray tube with respect to the center of the grid and the center of the film. It is just as important that this be done with the stationary focused grid as it is with the usual type of Potter-Bucky diaphragm in order to avoid uneven density across the film. Displacing the tube from the grid center has the same effect as does a transverse tube tilt. If the grid is of the unfocused type, the side of the film toward which the tube is shifted will be darker than the other; if the grid is of the focused type, it will be lighter. It should be recalled that the shifts referred to are at right angles to the direction of the strips. Tube displacements parallel to this direction will have no effect on the density of the film.

It is important to recognize that a focused grid has a "tube" side and a "film" side. If these surfaces are accidentally reversed, the grid absorption will be extremely high, except for a narrow strip in its center. The radiograph will be quite light, if not blank, except for the small portion under the perpendicular lead strips in the center of the film. In order to differentiate the grid surfaces some form of marking is always placed on the side of the grid which is to face the tube. If the grid has its elements perpendicular to its base (unfocused), it may be used with either side up. The direction of the grid strips is usually indicated by a line on the grid surface.

While modern stationary grids are mechanically strong and rigid, it is possible to seriously damage them by careless use. It may be necessary to use a film of a size smaller than the dimensions of the grid. If the cassette is placed under the grid and the patient's weight rests upon it, there may be a great mechanical strain over the unsupported sections of the grid which may damage it. To prevent such destruction, a number of wooden frames may be made, each of them having outside dimensions equal to those of the grid with apertures equal in size to the various cassettes which may be employed. The weight of the patient will then be supported by the frame outside of the cassette, and the likelihood of damage will be considerably reduced.

4. The Potter-Bucky Diaphragm

One objection to the use of the stationary grid is the appearance on the radiograph of a series of grid shadows. If, during the exposure, the grid is moved at right angles to the direction of its elements, the grid shadows should be eliminated since no single opaque strip will overlie the x-ray film in the same place for the entire exposure. The principle of the moving grid was devised by Dr. Hollis E. Potter in recognition of whom the device is called the Potter-Bucky diaphragm. In modern design it is generally an integral part of the x-ray table, mounted on rollers directly beneath the table top. There are several sizes of Potter-Bucky diaphragms which are made to be used as portable units.

Figure 163 is an illustration of a Potter-Bucky diaphragm as seen with the top removed. The grid (1) is actuated by a spring (2) working against the mechanical resistance of a piston moving in an oil-filled cylinder (3). The distance traveled by the grid is approximately 2 inches, moving from its initial position shown by the dotted line to which it is set by pulling the lever (4). The velocity of the grid is controlled by the timing device (5) which operates directly on the piston (3) to regulate the rate of its displacement through the cylinder. A dial indicates the time of grid travel which, on a modern high speed assembly, can be varied from 1/10 second to 40 seconds.

It is necessary that the grid be in motion before the exposure is started and that it continue for a short time after the exposure is terminated in order to prevent the appearance of grid lines in the periods of acceleration and deceleration of the grid. The simplest form of release, now largely outmoded, is a pull string fastened to a catch on the actuating spring. The string releases the grid, a bell rings after the grid has accelerated, and a second bell rings as the grid begins its deceleration. The exposure must be completed between the sounding of the bells.

An improvement over the string release is the electromagnetic trip, which permits remote push button control.

This release is actuated by the exposure switch setting the grid in motion. After approximately 10 per cent of the total grid travel, uniform velocity will be attained, at which time a set of

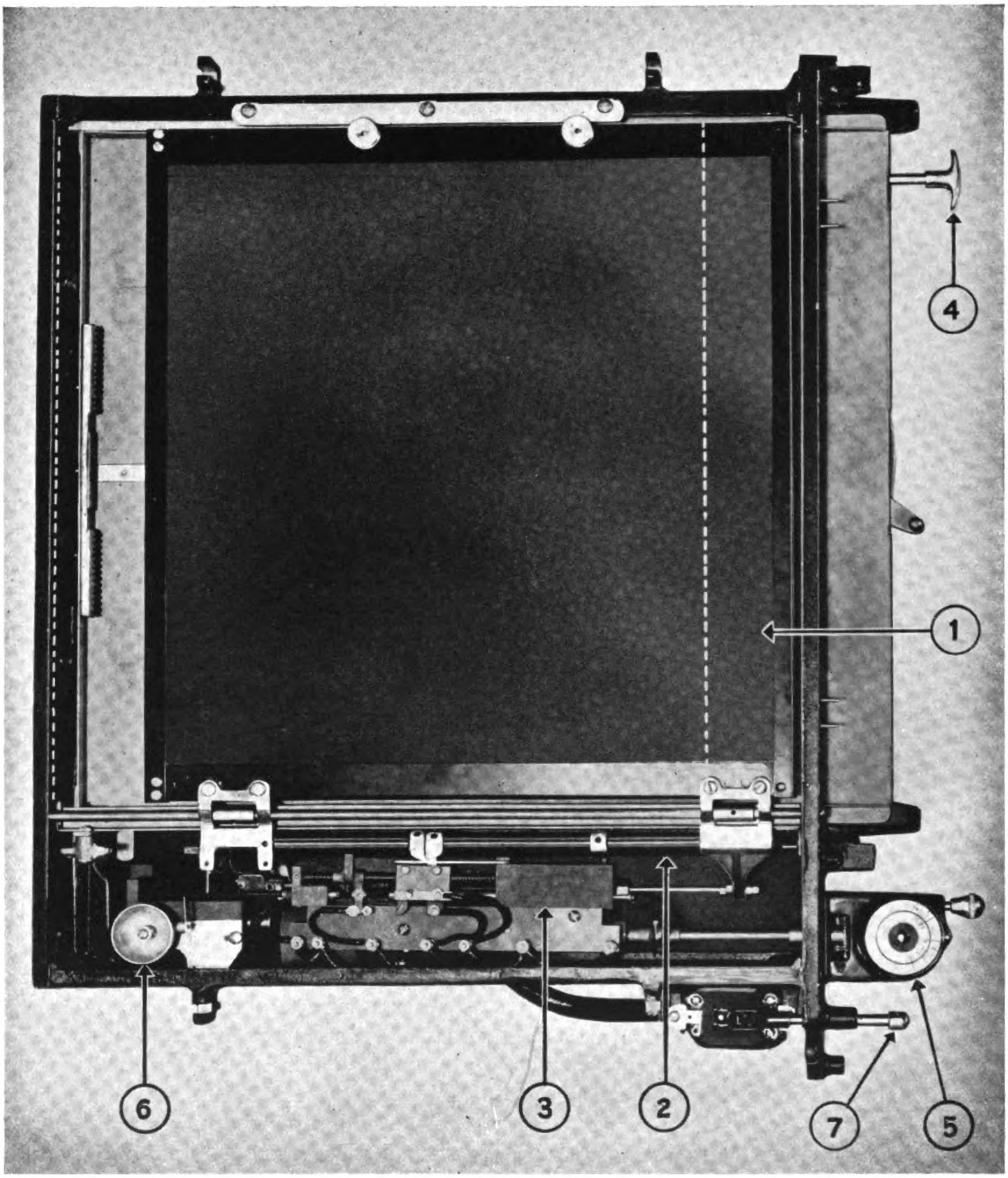

FIG. 163. Components of a Potter-Bucky diaphragm with the top removed.

contacts is automatically closed, starting the x-ray exposure. This is controlled by the timer which terminates the exposure. The grid continues to move, coming to rest after the exposure has terminated. If, by mistake, the bucky control is set for a time shorter than the timer setting, grid lines are prevented by an automatic shutoff feature operating through the machine control which opens the circuit just prior to the termination of the grid travel. A bell (6) is retained in the interlock mechanism mainly as an indicator of travel termination. A cutout switch (7) short-circuits the interlock mechanism for non-bucky technic. This switch is often incorporated in the central control apparatus so that it can be coördinated with other machine settings.

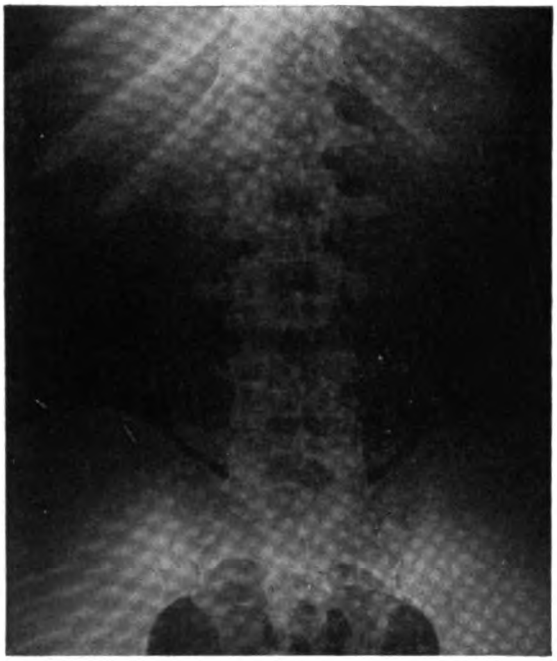

FIG. 164. Radiograph of an antero-posterior spine taken without the Potter-Bucky diaphragm.

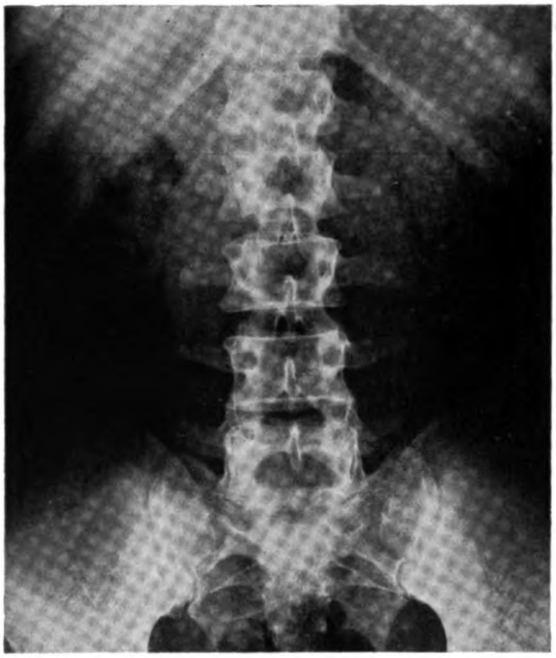

FIG. 165. Radiograph of an antero-posterior spine taken with the Potter-Bucky diaphragm.

The setting of the bucky timing control (5) must be such that the exposure can take place through its period of uniform travel. If the dial is set for 120 per cent of the exposure so that the grid will travel longer than the actual timer, there will be sufficient overlap to permit full exposure. The grid travel time can easily be checked when desired by comparison with the exposure timer for 2, 5, or 10 seconds and making any adjustment necessary on the timing dial. If the grid travel time is much longer than the exposure duration, the x-ray tube will be off center with respect to the grid during its effective travel; i.e., during the exposure. The result will be uneven distribution of x-ray energy to the film, and a non-uniform density of the radiograph.

The function of the Potter-Bucky diaphragm is to absorb secondary radiation by the interposition of opaque strips between its source and the film. The effect of this absorption is shown in the illustrations.

Figure 164 is a radiograph of an antero-posterior spine taken without the Potter-Bucky diaphragm; Figure 165 is made with the diaphragm. It is plainly evident that in the first, sufficient secondary radiation has been produced to markedly fog the film and obscure the areas of normally lesser density. The absorption differentiation within the tissues themselves is, as a result, greatly decreased; this effect is apparent on the film as loss of radiographic contrast. Tissue differentiation is very much improved and the quality of the radiograph greatly increased by the absorption of a high percentage of secondary radiation in the Potter-Bucky diaphragm.

There are some precautions which must be observed in the use of the Potter-Bucky diaphragm:

1. The grid travel time should not be more than 20 per cent greater than the duration of the radiographic exposure. With greater variation, there will be an uneven distribution of density over the surface of the film and an increasing possibility of grid shadows.
2. The focal-film distance should be within plus or minus 25 per cent of the radius of the diaphragm. A 40-inch grid may be used from 30 inches to 50 inches, and a 30-inch grid from 22 inches to 38 inches without excessive variation in film density crosswise the grid. If distances beyond the limits recommended are employed, there will be

loss in density outward from the center of the film. Figure 166 is a series of exposures at various focal-film distances, 30 inches, 40 inches, and 50 inches with a Potter-Bucky diaphragm grid having a 40-inch radius. Note the falling off of density toward the edges of the film.

3. The x-ray tube should be positioned to the center of the Potter-Bucky diaphragm. An off-center position will result in nonuniformity of film density and the possibility of grid lines. In stereoscopic technics with the shift crosswise, it may be found necessary to increase the exposure slightly

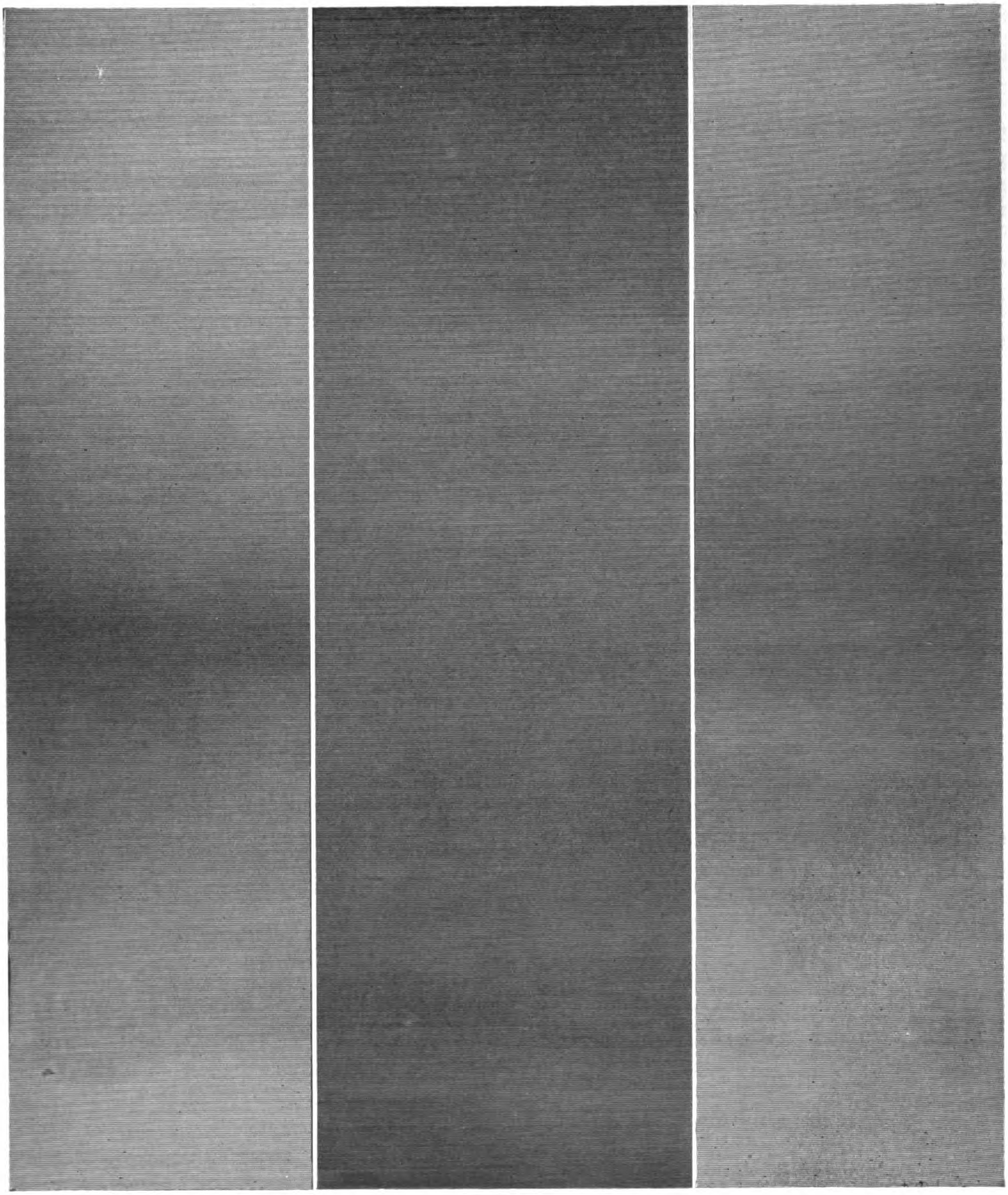

FIG. 166. Radiograph of a stationary grid taken at 30 inches, 40 inches, and 50 inches.

for one of the films to equalize the density for both. Figure 167 is a radiograph of a pelvis taken with the tube 4 inches off center toward the right side of the patient at a distance of 40 inches. The difference in density between the right and left portions of the film is quite marked. If the tube is shifted parallel with the grids, densities will be equal on both films.

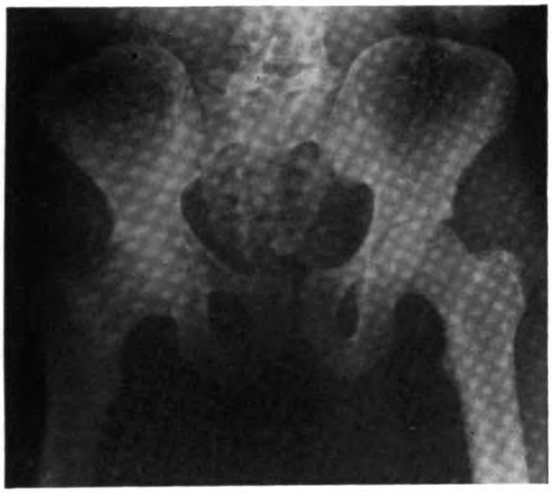

FIG. 167. Radiograph of a pelvis taken with the tube 3 inches off center toward the right side.

4. The grid must be allowed to reach a uniform rate of travel before beginning the x-ray exposure. With an electrical interlock mechanism, this is automatically arranged. If an interlock is not incorporated, about 10 per cent of the exposure time must be allowed for acceleration.
5. The grid must be traveling at uniform rate of travel when the exposure is terminated. The "slowing down" period must be considered in setting the grid travel time. If the exposure is continued beyond the period of uniform travel, grid lines may result. If the exposure continues after the grid comes to rest, they are certain to appear. The electrical interlock mechanism safeguards against this occurrence by automatically terminating the exposure as the grid begins to slow down.
6. Tube tilts angulated across the direction of the grid strips should be avoided. Tube tilts parallel to the direction of the strips will have no effect on absorption.

a. Application of the Potter-Bucky Diaphragm

The applications of the Potter-Bucky diaphragm to radiographic technic are extensive, including all areas of sufficient thickness and opacity to set up disturbing secondary radiation. So important is this device that only the lighter extremities and a small number of regions in the skull can be excluded from those in which marked improvement in quality can be effected.

As previously stated, limiting the area through the use of proper cones aids materially in reducing secondary radiation. The combination of proper cones with the Potter-Bucky diaphragm provides the ideal method for producing the maximum in tissue differentiation.

(1) *Pelvis and Spine.* The pelvic and spinal regions, because of their greater opacity, require x-ray energy values in excess of those employed for most other parts of the body. The resulting secondary radiation interferes to an objectionable extent with the quality of the film.

(2) *Ribs and Sternum.* The ribs below the diaphragm require a bucky procedure since the energy employed approximates that for the lumbar spine exposures. Above the diaphragm, the opacity is very much less and non-bucky procedures may be acceptable. However, in the oblique and lateral views on moderately heavy patients, there is objectionable scattering which may, with advantage, be removed by utilization of the Potter-Bucky diaphragm.

The sternum in the lateral position does not require the grid, though results are improved with its use. In the oblique projection there is a necessity for increasing contrast because of the low inherent differentiation between the sternum and the surrounding tissue.

(3) *Skull.* The lateral skull is similar in opacity to the pelvis. The problem of secondary radiation is very much the same with the exception that small areas are frequently radiographed, permitting the use of small cones or field-limiting devices which reduce to some extent the scattered radiation. The optic foramen may thus be filmed with a 2-inch cone and fair results may be obtained. For the lateral, antero-posterior, postero-anterior, and occipital projections Potter-Bucky technics are desirable. The exceptions may be certain emergency cases where injuries prevent the removal of a patient from a

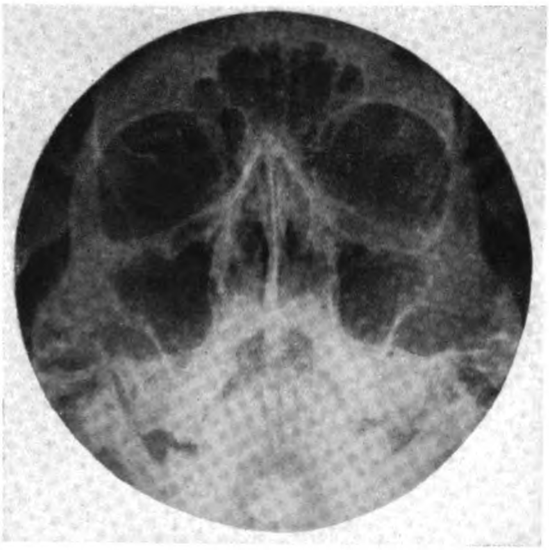

Fig. 168. Radiograph of the maxillary sinuses taken without a Potter-Bucky diaphragm, 4-inch cone.

bed or hospital cart in which case the stationary grid may be used.

(4) *Sinuses.* In radiography of the sinuses, a 4-inch cone or extension cylinder is commonly employed. By so limiting the field of radiation, acceptable results may be obtained without the Potter-Bucky diaphragm, though greater contrast is obtained with it. Figure 168 is a radiograph of the maxillary sinuses made without a Potter-Bucky diaphragm but with a 4-inch cone.

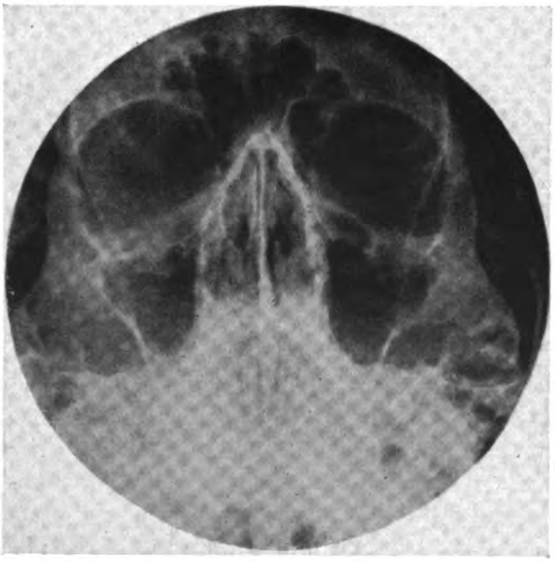

Fig. 169. Radiograph of the maxillary sinuses taken with the cone and the Potter-Bucky diaphragm.

Figure 169 is a radiograph made with the cone and the Potter-Bucky diaphragm.

(5) *Mastoids.* The mastoid cells, because they may be covered in a small cone circle, are most satisfactorily filmed without the Potter-Bucky diaphragm, though in the lateral projection some improvement is noticeable with it. Since a distance of only 22 inches or 25 inches is generally employed, the energy values are fairly low. The combination of the 2-inch cone and low x-ray energy is in the direction of reducing secondary radiation, thus making the Potter-Bucky diaphragm unnecessary.

(6) *The Extremities.* Radiography of the heavier regions in the extemity group may be improved through the use of the Potter-Bucky diaphragm. The knee, the femur, and the shoulder are generally sufficiently opaque so that best results are obtained only with the reduction of secondary radiation. The ankle of a large patient may also fall in this class, particularly if in a cast. When a non-screen type of film is employed for the heavier extremities, the Potter-Bucky diaphragm is essential if results of the highest quality are to be obtained.

(7) *Chest.* On heavy patients, or in certain types of pathology, the Potter-Bucky diaphragm is a distinct aid in producing better quality films. With the advent of high-speed bucky grids and mechanisms, exposures of 1/10 and 1/20 second are possible without the appearance of objectionable grid shadows on the film. It is to be expected that in the future more bucky chest work will be done, particularly for the type of patients mentioned above and for lateral projections on individuals of even moderate size.

(8) *Internal Organs.* Radiography of the gall bladder and urinary tract requires a Potter-Bucky technic for acceptable results.

(9) *Stomach and Colon.* Though it is true that a barium-filled stomach or colon possesses a high degree of inherent differentiation, secondary fog is present particularly in the case of heavy individuals, and can advantageously be eliminated through the use of a Potter-Bucky procedure.

H. Absorption Characteristics of the Body

The radiographic image is a record of the journey of the x-ray beam from the tube focal spot to the film surface upon which the film-blackening effect is proportional to the energy remaining after passage through the absorbing medium. This remnant energy depends on the intensity of the incident beam, the nature of the absorbing medium, and its intervening thickness.

Figure 170 is a qualitative demonstration of the absorption process in which I_0 is the initial beam intensity measured at the proximate surface, I is the intensity of the beam as it leaves the absorbing medium, X is the thickness of the intervening structure, μ is a number characteristic of the material and known as its absorption coefficient and e is the base of the natural system of logarithms, 2.718.

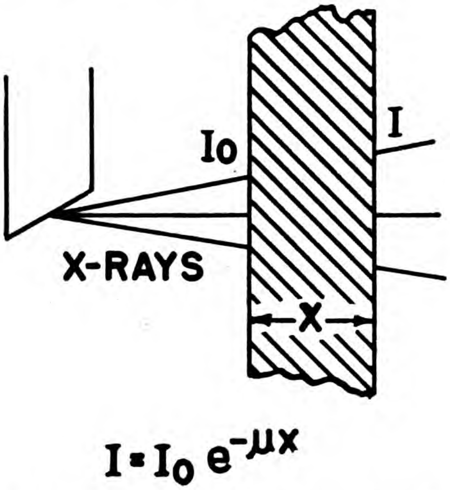

FIG. 170. Diagram illustrating linear absorption.

The equation indicates that the diminution of energy is a function of the quantity remaining at any point in a logarithmic decay form. The coefficient μ_m is of great interest since it may be expressed in relation to unit mass of the absorbing material and, as such, a measure of its absorbing power:

$$\mu_m = \frac{\mu}{e}$$

in which e is the density of the substance.

Since we rarely radiograph elemental material but are generally confronted with compounds and combinations of compounds, it is of convenience to express the absorption function in terms of the energy absorbed per molecule. Knowing that the mass absorption coefficient is independent of the physical state of the material and that the energy absorbed per atom is independent of its form of chemical combination, it is relatively simple to compute molecular absorption coefficients for the substances encountered in radiography and to establish their relative opacities from such figures.

The relationship thus far derived holds for restricted conditions:

1. The radiation must be homogeneous.
2. The beam must be small in section.
3. The material must be homogeneous and uniform in thickness.

Since these conditions in x-ray practice are approximated but not attained, precise calculations are hardly significant. However, some deductions may be made of relative absorption based on what is known of the chemical constituents of calcium carbonate, water, and air, three of the principal constituents of bone tissue, soft tissue, and lung tissue.

From calculations made using the preceding formulae, the table in Figure 171 is compiled.

Element	*μm*	*Z*	*A*	*μa*
Hydrogen	0.375	1	1	$.062 \times 10^{-23}$
Oxygen	0.183	8	16	$.488 \times 10^{-23}$
Nitrogen	0.179	7	14	$.412 \times 10^{-23}$
Carbon	0.175	6	12	$.350 \times 10^{-23}$
Calcium	0.520	20	40	3.47×10^{-23}

FIG. 171. Absorption coefficients for materials of which the body is composed.

Multiplying the atomic absorption coefficient by the number of atoms per molecule, the molecular absorption coefficients of Figure 172 are obtained.

Material	*Coefficient*
Air	0.435×10^{-23}
Water	0.612×10^{-23}
Calcium Carbonate	5.28×10^{-23}

FIG. 172. Molecular absorption coefficients for various substances.

These numbers express in a purely relative manner the absorbing power of the principal materials through which the x-ray beam is directed in radiographing the human body. It is evident that bone tissue is much more opaque than the soft tissue and that the lungs largely filled with air offer relatively little obstruction. There results on the film a pattern of densities established by the total opacity of the transverse tissue in the path of the x-ray beam for each area unit of its surface. The contrast between adjacent areas leads to the visible differentiation of tissue structure wherein lies the diagnostic value of the radiograph. This contrast is established by the differential absorption which, as has been shown, is a function of the thickness of the absorbing material and of its nature.

It is necessary to point out that the absorption coefficient for any substance is not a constant, but is different for different wavelengths of x-rays. There are sharp discontinuities for certain critical wavelengths which greatly affect their behavior. The values as obtained are significant only when a homogenous beam is employed and the absorbing material is pure.

For these reasons the determination of x-ray technics based on accurate knowledge of tissue density and thickness is impractical. Such information as we now possess is entirely empirical, and is established on the basis of x-ray energies required for various regions of the body, the variation in energy per centimeter thickness of tissue for these areas, and the effects of inspiration, expiration, compression, disease, atrophy, etc.

I. Radiographic Opacity

The absorption of x-rays is a function of the thickness of the absorber, its absorption coefficient, and of the nature of the x-ray beam. The theoretical law is a simple exponential, $I = I_0e^{-\mu x}$; but the complex nature of the coefficient μ has led to the use of empirical information related, in radiography, to the energy required for various regions of the body and the variation per centimeter thickness of tissue for these areas. The quality of the radiograph will depend on the degree of differentiation of tissue structure in adjacent areas which, in turn, is established by contrast, density, and sharpness of detail.

The specification of acceptable standards for radiographic quality has, as yet, been unsatisfactory. The complexity of structure, the great variation in densities over the film surface, and differences in individual preferences among observers are factors which have thus far been insurmountable. The establishment of radiographic standards and technical factors, as tube voltage and milliampere-seconds, which can be used in reproducing such standards, is further complicated by the fact that the quantity and quality of x-ray output are not universally specified by the electrical input to the x-ray tube expressed in kilovolts peak and milliampere-seconds.

Any portion of the film area is a record of what is left of the x-ray beam after passage through the intervening structure, a complicated combination of bone, soft tissue, and muscle in varying thicknesses and degrees of concentration. The eye, viewing the film by transmitted light, is able to differentiate areas because of differences of density or contrast. Some data can be obtained photometrically by placing a photoelectric cell and galvanometer as shown in Figure 173 and measuring the transmitted light for various regions of the film, and expressing the absorption in terms of film density units, a unit being that density which will reduce the transmitted light to 1/10 of the incident light.

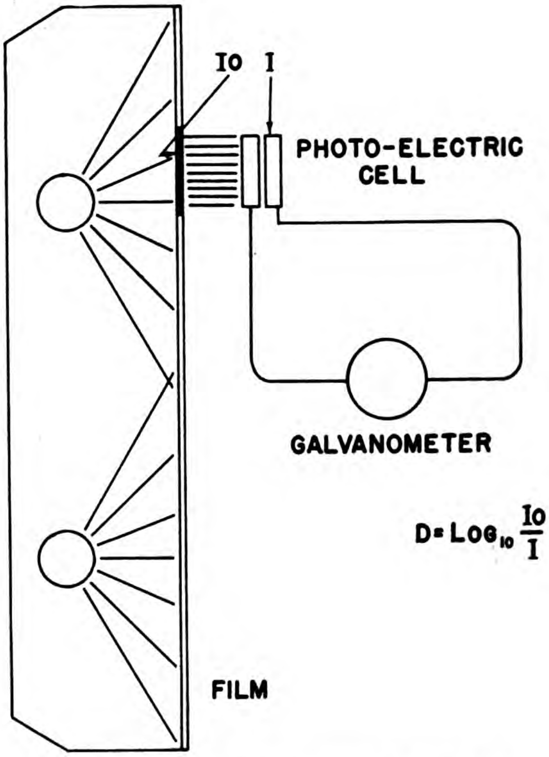

FIG. 173. Method for measuring light intensities and film densities.

The general formula is

$$D = \log_{10} \frac{I_0}{I}$$

in which I_0 = intensity of incident light
I = intensity of transmitted light

The values for substitution in the formula were obtained by reading the light intensity with the film removed (I_o), then reading the intensity over any desired area on the film (I). The logarithm of the ratio is the density. If the densities for two adjacent areas were D_1 and D_2, the contrast is expressed as

$$C = D_1 - D_2$$

In analyzing the effects of tissue opacity, we can make use of such physical expressions for density and contrast to illustrate the absorption properties. In obtaining the following data, radiographs of the highest possible quality were made of the pelvis, the shoulder, the skull, the chest, and the lumbar spine so that all combinations of tissue structure could be studied. Photo-electric measurements were made for various regions in the film and the corresponding densities were calculated, Figure 174. Keeping in mind the fact that a density value of 1.0 represents a 10 to 1 ratio of incident to transmitted light, while a density of 2.0 is a 100 to 1 ratio, a concept of the variation present in a radiograph of excellent quality can be formed.

Pelvis
Antero-Posterior

Area	*Density*
Iliac Crest	2.30
Sacro-Iliac	0.42
Femoral Head	0.40
Pubic Symphysis	0.67
Sacrum	1.15
Soft Tissue above Crest	3.00

Lumbar Spine
Lateral

Area	*Density*
First body (center)	1.12
Second body	1.40
Third body	1.46
Fourth body	1.33
Fifth body	0.94
Intervertebral space	1.60
Anterior soft tissue	2.00
Posterior soft tissue	3.50

Skull
Lateral

Area	*Density*
Frontal	2.00
Parietal	1.07
Occipital	0.89
Sella turcica	1.32
Petrous portion	0.26

Shoulder
Antero-Posterior

Area	*Density*
Head of humerus	1.52
Clavicle, acromial end	2.22
Glenoid fossa	0.38
Body of scapula	0.88
Clavicle, sternal end	1.14

Chest
Postero-Anterior

Area	*Density*
Apex	0.4
3rd and 4th interspace, right	1.00
Base, right	1.19
8th and 9th interspace, left	1.19

FIG. 174. Film density measured on typical radiographs.

J. Effect of Tissue Thickness

The effect of tissue opacity on density and contrast has thus far been analyzed from the point of view of (1) the absorption characteristics of bone, muscle, and soft tissue, and (2) the film response to differential absorption of x-rays passing through the region being radiographed.

Repeating the general absorption law for the passage of x-rays through matter,

$$I = I_0 e^{-\mu x}$$

in which x is the thickness of the absorber, μ is a factor relating to its absorbing power and the incident and remnant intensities are I_o and I respectively. From this expression, which in a practical sense is only approximated, it is seen that the thickness of the part is not a complete specification of its total absorbing power, but must have associated with it some form of absorption characteristic dependent upon the nature of the material. It is this factor which introduces the indeterminate element in x-ray technic, an element based on the condition of the patient, such as atrophy due to disuse, age, disease, etc. Were it not for such variables, it would be possible to devise an exact x-ray technic chart based on the thickness of the part and the variation in x-ray intensity per unit thickness expressed usually as kilovolts peak per centimeter. Despite the so-called "patient variable" with respect to tissue thickness, the measurement of part procedure is of particular value especially to the technician lacking the experience to successfully judge technic by measuring with the eye. Figure 175 is a typical chart based on thickness of part.

Region	*Distance*	*Milliampere Seconds*	*Kilovolts Peak*	*Centimeters*
Skull, antero-posterior	40 inches	100	64	19
Shoulder, antero-posterior	40 inches	40	50	14
Cervical Spine, antero-posterior	40 inches	50	56	13
Dorsal Spine, antero-posterior	40 inches	200	60	21
Lumbar Spine, antero-posterior	40 inches	200	64	18
Lumbar Spine, lateral	36 inches	300	70	28
Pelvis, antero-posterior	40 inches	200	60	20
Chest, postero-anterior (no bucky)	72 inches	15	54	20
Stomach, postero-anterior	40 inches	75	68	20

FIG. 175. Typical technic chart based on thickness of the parts to be radiographed.

The variation in kilovolts peak per centimeter thickness with screens usually varies from 2 to 3 kilovolts peak, depending on the initial kilovolts peak value.

Thus, the technic for an antero-posterior skull measuring 22 centimeters would be 64 kilovolts peak + (3 × 2) or 70 kilovolts peak; for a lateral lumbar spine measuring 34 centimeters, the required voltage would be 70 kilovolts peak + (6 × 3) or 88 kilovolts peak; and a chest 27 centimeters in thickness would require 54 kilovolts peak + (7 × 2) or 68 kilovolts peak. It is to be understood that the actual values given above depend to a great extent on the output characteristics of the x-ray machine, the speed of the intensifying screens, the sensitivity of the film, the activity of the developer, and the absorption of the Potter-Bucky diaphragm. These factors are standardized by a series of test radiographs made on measured subjects of average tissue density and a single compensating factor is introduced as an additive or subtractive constant expressed in terms of kilovolts peak. Such a procedure, with a complete chart of the form illustrated, will lead to a standardized technic chart based on measurement of part thickness for each region of the body and will provide a reasonably satisfactory basis for at least a partial specification, freed from the variability of rules of thumb and subjective errors.

Since the factors are selected in accordance with the technical requirements of each region, the variations about the average thickness should theoretically be sufficiently compensated for by changes in x-ray energy to produce a range over which the results are of the highest possible order. For example, all chest technics are based on the selection of the most satisfactory values of milliamperage, time, kilovolts peak, and distance for chests of average thickness; all lateral lumbar spine technics on the optimum factors for the average lateral lumbar spine; all antero-posterior skull technics on the most suitable combination for the best radiograph of this particular region. This procedure eliminates the most common source of error in measurement-of-part technic tables, that of extending factors indiscriminately from one region to another simply on the basis of a change of tube voltage to compensate for differences in thickness without cognizance of the necessity for varying time, tube current, and often the distance for various areas of the body.

Unfortunately, even with the restricted range of variation of the foregoing procedure, a considerable exercise of professional judgment must influence the final choice of the single variable, kilovolts peak. This judgment must be applied to the indeterminate factor of tissue opacity, the absorption per unit thickness, the μ of the absorption law for x-rays. Influenced as it is by the age of the patient, his body configuration, by disease, and by atrophy due to disuse, this factor is one of great importance in its effect on density and contrast of the radiograph.

K. Body Configuration

Tissue opacity per unit thickness in most regions is greater for the short, stocky individual than for the tall, thin type. The distribution of muscular tissue affects the energy required for equivalent radiographic densities by from 5 to 10 kilovolts peak, the exact value depending on the region being radiographed and the tube voltage. The factor of kilovolts peak must be considered because the response characteristic of intensifying screens and films together with the non-linear relationship of x-ray output combine to make small changes much more effective at low values than at high. As examples, the table, Figure 176, gives the change in tube voltage necessary to double or halve the density on a film with Parspeed intensifying screens.

Initial Kilovolts Peak	*Change in Kilovolts Peak*
30	3
40	4
60	10
80	16

FIG. 176. Approximate change in tube voltage necessary to double or halve the density on a film, with intensifying screens.

Considering further the problem of body configuration, certain areas will be less affected than others by such structural differences. The skull, sinuses, mastoids, and teeth are relatively unaffected; the spine, G-I tract, G-U tract, gall bladder, much more so, and the lungs to some intermediate value. Assuming a reference level of 60 kilovolts peak, the compensation will be somewhat as shown in Figure 177.

L. Muscular Condition

The muscular tone of the patient will have a noticeable effect on film density and contrast. Individuals engaged in active work requiring muscular exertion develop an increased tissue opacity which, in some cases, may require an addition of 10 kilovolts peak over the average technic. A person whose habits and work are sedentary will, on the other hand, exhibit a lesser opacity for the same thickness, requiring a decrease in penetration of perhaps 6 kilovolts peak under the average. These figures are approximate and are subject to the same modification for different regions of the body as indicated in the preceding table. For these regions in which muscular development has little effect, as the skull, sinuses, mastoids, etc., the technic may require no compensation. In the shoulder and abdomen, well-developed musculature greatly increases the opacity of these areas, while there will be a marked effect, though to a lesser extent, in radiography of the extremities. No precise values of compensating x-ray energy can be given because there is no known method for measuring a person's muscular condition; judgment and estimation from previous experience are the only guides, within the limits expressed in the preceding paragraphs.

M. Disease and Atrophy

The tissue changes resulting from disease and atrophy affect x-ray opacity to an extent even less determinable than the classes already discussed. A fluid-filled lung greatly increases the absorption of this region; a partially atrophied bone is much less opaque than the normal. The degree of compensation to the average technic required for pathological changes is very often unpredictable when the patient first presents himself, making necessary the acceptance of a "first film" which may be markedly under or over exposed. By examination of this initial trial, the technician should be able to cor-

Region	*Compensation*		
	Short, Heavy	*Average*	*Tall, Thin*
Skull, extremities	0 kilovolts peak	0 kilovolts peak	0 kilovolts peak
Lungs	+4 kilovolts peak	0 kilovolts peak	−4 kilovolts peak
Other internal organs	+6 kilovolts peak	0 kilovolts peak	−6 kilovolts peak

FIG. 177. Effect of body configuration on average radiographic technic.

rectly estimate the increase or decrease in tube voltage necessary to produce the desired density. The table in Figure 176 gives the voltage necessary to double or halve the density at various initial values.

Contrast as well as density is affected by the presence of changes due to disease or atrophy. The differentiation between adjacent structures following atrophy of the bone, for instance, may decrease radiographic contrast to a surprising extent so that technic conversions may be necessary to produce the best film. The technician should be able to recognize the appearance of a "flat" film resulting from changes in the nature of the tissue and to alter the technic to increase contrast, if desirable.

The various factors affecting tissue opacity may be cumulative or some may cancel others in a particular case. Over a large number of patients representing all sizes, body configuration, musculature, state of health, and age, which are likely to be encountered in practice, a statistical distribution of variations becomes evident. Restricting the field to adults, for example, one will find that the greatest percentage will require what has been classed as the "average" technic, based on the opacity of a 5 foot 8 inch male weighing 150 pounds, or a 5 foot 2 inch female weighing 120 pounds. For the greatest percentage of radiographs, the variations from technics required for this type of person in moderately good health will be relatively little. The number corresponding to large variations will, on the other hand, be decreasingly small. It is possible then to set up certain limits of variations which include a large percentage of all adult subjects which are likely to be encountered in radiography. The variation will be different for various areas of the body and will depend on the nature of the recording medium as well as the initial value of tube voltage. The table, Figure 178, has been prepared for Parspeed screens at voltages normally employed in radiography of the parts specified.

The variations are given in terms of kilovolts peak, the difference between the maximum and minimum values over a large number of subjects, as determined from actual experience.

Part	*Variation*
Wrist	9 kilovolts peak
Elbow	12 kilovolts peak
Shoulder	15 kilovolts peak
Ankle	12 kilovolts peak
Knee	14 kilovolts peak
Skull	14 kilovolts peak
Sinuses	14 kilovolts peak
Mastoids	8 kilovolts peak
Cervical Spine	12 kilovolts peak
Dorsal Spine	18 kilovolts peak
Lumbar Spine, antero-posterior	18 kilovolts peak
Lumbar Spine, lateral	24 kilovolts peak
Pelvis	18 kilovolts peak
Lungs	20 kilovolts peak
Kidney	18 kilovolts peak
Gall Bladder	21 kilovolts peak
Stomach	21 kilovolts peak
Colon	18 kilovolts peak

FIG. 178. Usual range of variation in terms of kilovolts peak for certain regions of the body, with Parspeed screens.

N. Tissue Differentiation

1. Opaque Media

The contrast between adjacent areas is determined by the differential absorption which depends on the thickness of the absorbing tissue and its nature. The characteristics of bone, muscle soft tissue, and the air cavities of the body are such that differences between their x-ray absorption are relatively great except for modifications introduced by the effect of disease and atrophy. For many areas of the body the inherent differentiation of adjacent structures is not sufficiently great to permit visualization on the radiograph. The esophagus, stomach, colon, kidney, urinary bladder, and gall bladder are examples of organs which require the introduction of substances having in themselves greater opacity than the tissue surrounding these parts of the body. The nature of the opaque medium depends on the particular portion of the anatomic system into which it is to be absorbed or introduced, and are so varied that they may be best treated separately.

a. Gastro-Intestinal System

In radiography and fluoroscopy of the gastrointestinal tract, the basic opaque medium is barium sulphate, a material obtained by precipitation from barite, vacuum dried and pulverized to produce a finely divided white substance of molecular weight 233 which, after mixing with water, forms a suspension for administration orally or by enema. In order that the preparation more nearly approximates the normal motility of food taken into the stomach, the barium sulphate is usually mixed with specially processed cereals, flavored with vanilla or chocolate for increased palatability. In such mixtures, the barium sulphate content is 70 per cent and 60 per cent respectively.

For the delineation of the oesophagus and rugae, a modification of the barium meal is made by adding a small quantity of a substance which causes it to adhere to the mucosa, increasing the radiographic or fluoroscopic contrast. The barium sulphate content of this preparation is usually 50 per cent, so that it is used in somewhat greater concentration for the usual examination.

From what has already been written of the factors affecting contrast, it should be known that the quantity of relatively high opacity material, in this case barium sulphate, must maintain a constant proportion of the total body thickness if the contrast is to be maintained. The quantity of opaque substance should be varied with the size and weight of the patient to maintain proportionality of the x-ray absorption of the body to the absorption of the opaque-filled portion of the gastro-intestinal tract being examined.

b. Gall Bladder

The variation in density from point to point in the radiograph is due to differential absorption of the x-ray beam in the various regions overlying the film. Where the differences normally existing within the body are insufficient to produce noticeable differences in density between adjacent areas on the film, there will be little or no visibility of structural outlines and no diagnostic value in the film.

In the case of the gall bladder, sodium tetraiodophenolphthalein is used for its visualization.

Preparations of this dye are available for oral or intravenous administration in cholecystography.

c. Urinary Tract

The urinary tract, composed of the kidneys, ureters, and the urinary bladder, like the organs mentioned above, are ordinarily not sufficiently opaque to be visibly differentiated on the radiograph. A number of substances have been developed for use in visualizing the urinary tract, the manner of administration being either directly into the kidney pelves or by intravenous injection.

CHAPTER VIII

The Processing Room

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TOO MUCH stress cannot be laid on the importance of processing room construction and technical procedures, whether it be for private practice or a large institution. It is realized that the quality of the end result depends entirely on the facilities and procedures used.

No radiograph is complete until it has passed through the development process. Experience proves that even with the best radiographic equipment and accessories, radiographic technic can be made mediocre by faulty processing room service. Yet is is doubtful if ten per cent of film processing laboratories the world over are on a par with the rest of the x-ray department in point of facilities to handle the work. A surprisingly large number of x-ray laboratories could produce much better routine radiographs than they do. These laboratories are handicapped because the equipment in the processing room and the haphazard procedures used fail to justify the investment made in the radiographic apparatus.

Many tools are used in the processing room. Each is discussed fully, and in a step-by-step procedure that brings the finished radiograph to its record file.

Radiography begins and ends in the processing room. An adequate processing room, proper handling of the films, loading of the cassettes or exposure holders, and unloading the same preparatory to the developing and fixing of the radiographs are procedures just as important as correct positioning of the patient, correct exposure time, and correct centering of the film, patient, and tube. Manufacturers continue to devote a great deal of time and money to the study of processing room procedures, for it is a subject of primary importance to every x-ray laboratory. Due to this study, new and improved devices are constantly being developed to aid the technician in the production of better radiographs and lighten the day's routine.

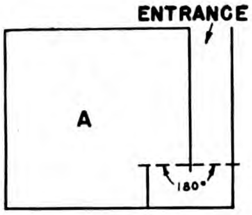
Location of Processing Room

An important consideration when planning a processing room is its location. First, it must be within a reasonable distance from the x-ray machine or machines. Second, it must be convenient to plumbing and electrical connections. Another important factor is ventilation. As a rule, the darkroom is built within another room and, even though it may have an outside window, it cannot be used for ventilation as white light must be completely shut out. Ventilation can be controlled effectively by the use of mazes and louvres located at various places in the darkroom. Forced draft film driers located in the processing room can also be used for this purpose.

Construction of Processing Room

Construction of the processing room and its mazes with reference to materials used is limited. It must be of such material as to preclude leakage of ordinary light and x-ray, where the source of the latter presents a problem. In this case the use of lead lining in the walls, facing the x-ray equipment, is necessary. The size of the processing room is determined by the nature and average amount of work that is to be handled. The minimum dimensions should still allow room for convenient and efficient processing room procedures. The number of entrances and exits will also depend on the average amount of work to be done. These are usually either doors or mazes or both. If considerable work is to be handled, mazes are generally used. For the average amount of work, a small ante-room may be used, constructed so that the outer door may be closed before the inner door is opened. This prevents light leakage to unprotected films. If the maze is used as a means of entrance and exit, its location should be convenient to the operator. The length of the maze must necessarily depend upon its location with reference to the processing room, the outer entrance, and the degree of turn before entrance to the processing room.

Construction of Maze



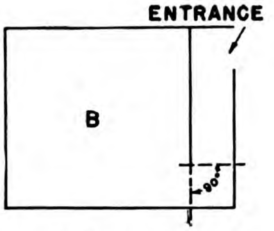


FIG. 179A. 180-degree maze. FIG. 179B. 90-degree maze.

If the maze is constructed similar to Figure 179 A, then a 180-degree turn is necessary. If, as in Figure 179 B, a 90-degree turn is sufficient. The width of the maze should not exceed that which will allow two persons to pass facing. This is done to conserve space for the darkroom proper.

Color Treatments of Walls and Maze

In respect to color treatment of the walls of the processing room and maze, it is apparent that there is much misunderstanding. Most x-ray laboratories utilize either black or some other dark pigment, which is not necessary. The problem of color selection for the maze is slightly different from that for the processing room. The former deals with absorption of intense light, such as sunlight or brilliant electric illumination, whereas the latter deals with subdued filtered illumination. Therefore the maze should be of a color which will preclude the possibility of intense light being reflected and entering the processing room. Thus a dark pigment should be utilized, such as a jet black or dark green and of a dull finish so that there is no reflected light. A strip of light color, at least four inches in width, at average eye level along the maze walls, will serve effectively as a guide. A safelight should be placed above the point of turn to illuminate this strip.

Many theories concerning processing room wall colors have been superseded by more practical considerations, due to the type of filtration in modern safelights. Thus, with light colored walls of special pigment there is a considerable increase in the amount of reflected safelight, and a resulting visibility never before enjoyed. It eliminates groping around the far corners of the processing room.

Black and white, acid, alkali, and water resistant paint may be used in the processing room to protect various surfaces, making them easy to clean. A black paint of the above type will provide a tough protective coat on the exterior surfaces of film processing tanks, tops of loading benches, and other wood or metal surfaces. A white paint may be used to advantage to increase the visibility of various objects in the processing room, that is, interiors of film driers, rims of master tanks and solution tanks, edges of shelves, loading benches, sinks, electric outlets, and tops of floating thermometers.

A combination of both black and white paint may be used to form a checkerboard or other pattern on the top of the loading bench or other working surfaces. This will result in greater visibility, enabling one to more readily distinguish all objects lying on these working surfaces.

Accessory Equipment

The following equipment is necessary within the processing room:

1. Safelights
2. Storage shelves or cabinets
3. Loading bench
4. Hanger racks
5. Solution tanks
6. Water temperature control
7. Thermometer
8. Timer
9. Drying equipment
10. Pass box

Illumination

Safelights cause a large percentage of processing room trouble. Fogging of the x-ray film is a phenomenon which the average operator may find difficult to trace to its source, that is, to determine whether it is caused by the safelight, x-ray, or chemical reaction. It is well to remember that there is no such thing as a "safelight" in the strict sense of the word. All safelights will fog sensitized emulsions by excessive exposure. Thus the problem of film exposure to light is an important one.

In the final analysis, the maximum amount of light intensity or wattage that may be used in the safelight is determined by the following four factors:

1. Location of safelight, i.e., safelight-film distance.
2. Safelight filtration, or the quality of light allowed to pass through the light filter.
3. Speed of placing film in hanger.
4. Speed of operation while observing stage of development and rinsing film, placing it into the hypo solution or fixer.

Due to the fact that the above factors, with the exception of No. 2, are variable, because of the speed of the operator's movements, there can be no set distance or intensity stated. One can find by experiment, however, what they should be under given conditions. A film should be processed, then the safelight intensity and the safelight-film distance varied until the fog is eliminated. Sufficiently fast movement should be followed in the procedures. It is important to have a safelight next to the developing tank that will allow the visualization of the entire surface of the larger film without danger of overexposure. It follows that the smaller the size of the illuminator, the greater is the risk of fog due to the fact that more time will be needed to check the entire surface area of larger film.

Storage Facilities

Storage shelves should be of such size as to allow the housing of all sizes of films, cassettes, and supplies. If a storage cabinet for films is used wherein the film package is uncovered, exposure and fogging of these films will result if the cabinet is accidentally opened in the lighted room. To avoid this, it is wise to have a master switch so placed that the light other than the safelight will be automatically turned off when the film cabinet door is opened.

Loading Facilities

The loading bench should be of a size which will allow the opening of film packages and loading of cassettes conveniently. If not wide enough, the film packages or cassettes may fall to the floor, ruining the films and possibly the cassettes. The loading bench should always be kept clean as any form of contamination may not only ruin the film to a point where diagnosis is nil, but also damage the intensifying screens. When possible, it is suggested that a waste paper basket be placed below or at least near the loading bench so that the ordinary film packings and black paper surrounding each film may be disposed of immediately rather than allowing this material to take up space on the loading bench or to fall to the floor.

Film Hangers and Racks

Hanger racks can be made of any material having sufficient strength to hold the hangers. Although wood is the most commonly used because of its decorativeness, they should be made so that each rack will allow its hangers to hang parallel to each other and located convenient to the operator, usually under the loading bench.

Film hangers are an important item in processing procedure. They should be stored in a convenient position. They must be kept clean; this can best be accomplished while the films they hold are being washed. At this time water should be passed over them. If this procedure is not heeded, stain is apt to appear at the point of clip contact. If the flexible arms of the film hangers become so weak as to allow the film to bulge, film scratching or stains may result due to contact when in solutions and cause film spoilage due to adherence of the emulsion. Hangers in this condition can be repaired in most cases. However, if they have reached the point where it is impossible to repair them, they should be removed from the processing room.

Tanks

Tanks for developing, rinsing, fixing, and washing should be of a size and capacity to meet any situation. They should be capable of maintaining temperatures and be durable, i.e., with minimum reaction to chemicals. Many tank combinations are available, the sizes and combinations depending entirely on the amount of work in each individual laboratory. In very busy laboratories it is usually found that additional tanks are required for proper and sufficient washing, as the

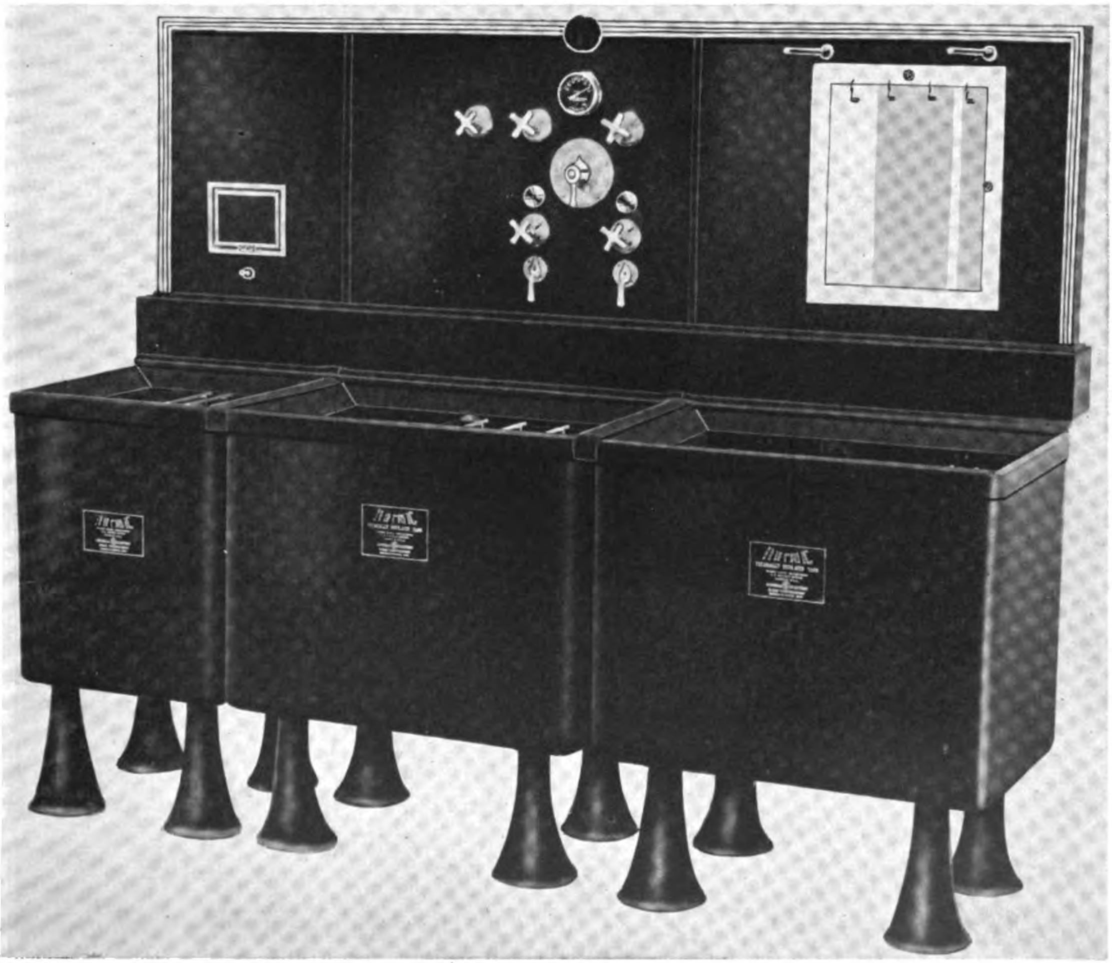


FIG. 180. Typical tank combination.

standard tanks are not sufficiently large to take care of the developing and fixing process, and still have sufficient room for washing. Insufficient wash space results in slowing down the processing rate since films cannot be processed until there is space in the wash compartment to accommodate them.

Water Temperature Control

Many developing difficulties are encountered in hot weather. This problem has been partially answered by the use of insulated developing tanks and artificial refrigeration. Complete units, including insulated developing and wash compartments, and refrigerating generators, are now available in many sizes and styles for processing room use (see Figure 180).

In hot weather, ice may be used to control the temperature of the developing solution. The ice should be placed in the wash compartment surrounding the developer and hypo containers, *but must never be placed in the solutions,* as this will dilute them and affect their strength and efficiency.

In the winter, it is sometimes necessary to heat the solutions or to bring them up to proper working temperatures. Warm water in the wash compartment surrounding the solution tanks is usually used for this purpose.

Care should be exercised that the water temperature is not sufficiently high to affect tanks constructed of material other than steel because of the possibility of bulging. Ordinary electric water heating units used directly in the solutions are very satisfactory for this purpose, provided the solutions are stirred constantly while the

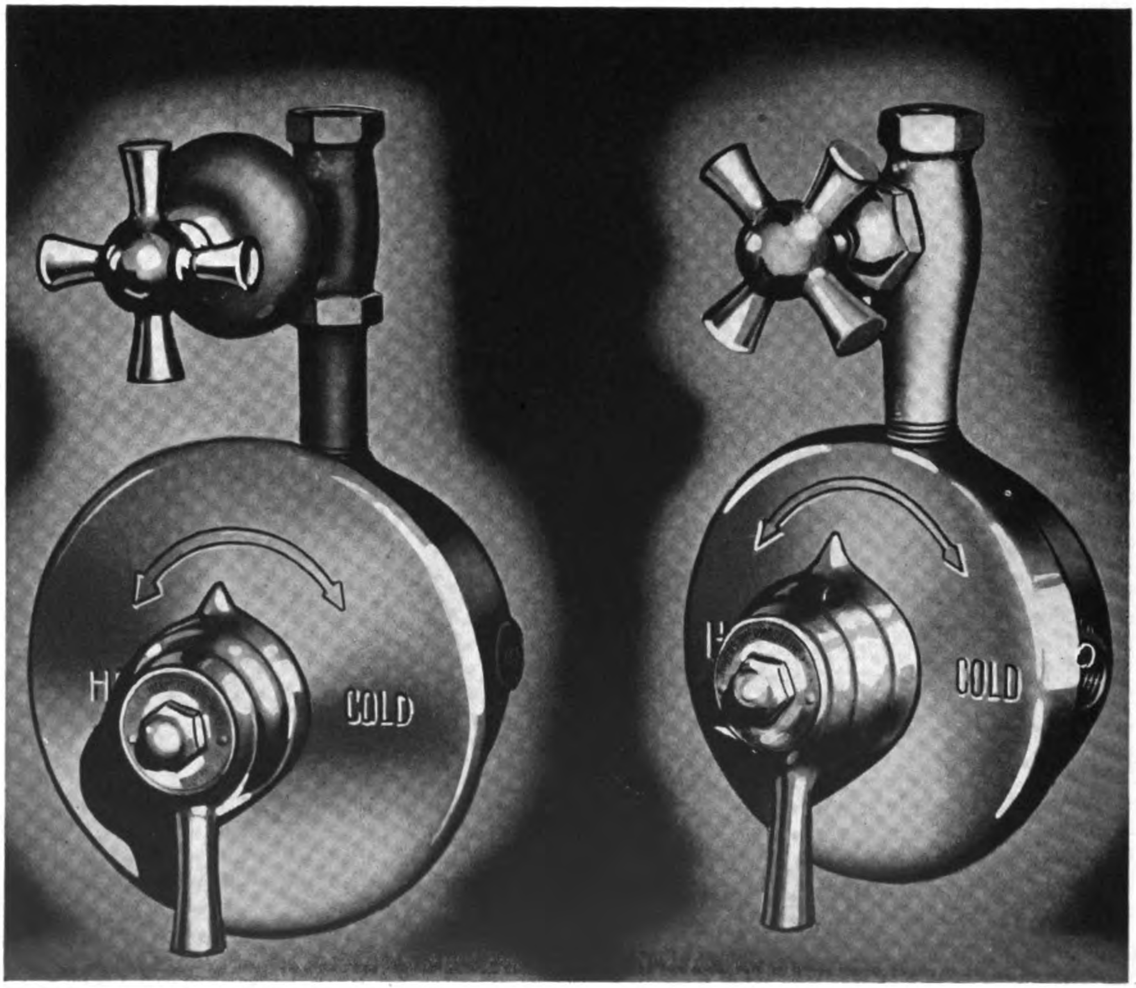


FIG. 181. Thermostatic valve.

heater is in operation. If this is not done, the excessive heat immediately surrounding the heating elements will cause the solution to oxidize more rapidly. Inexpensive wooden paddles may be purchased or made for the purpose of stirring the solutions. A thermostatic control valve connected into the plumbing system supplying the processing room will in most cases solve the problem of maintaining temperatures (see Figure 181). This type is known as the bi-metal thermostatic valve, and has a reasonable degree of accuracy, maintaining temperatures to within plus or minus 7 degrees. However, where water pressures are apt to vary and where hot and cold water supplies are inadequate or subject to change, an automatic water temperature blender may be necessary, as shown in Figure 182. This type of regulator controls the temperature of the water supply to the processing room tanks to within plus or minus ½ degree F. regardless of any change in water pressure in the plumbing system.

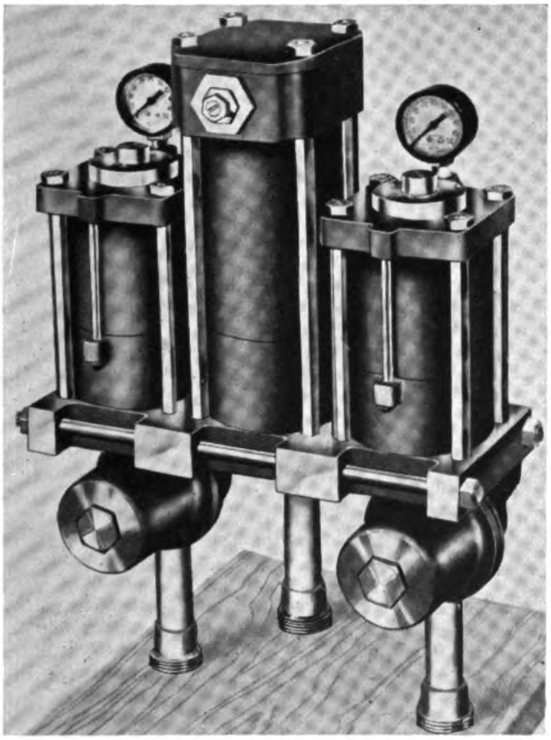


FIG. 182. Automatic temperature blender.

Many films are improperly washed after they have been processed. Where there is a good supply of fresh running water, films should be allowed to remain in this water for at least 15 minutes before they are dried. This will allow sufficient time for the fresh water to thoroughly rinse the soluble chemicals from the film emulsion, thus eliminating cloudiness, stains, and the frost-covered film so often seen.

Where running water is not available, or in cases where the running water is too warm, films should be washed at least thirty minutes with a change of water at regular intervals, depending on the number of immersed films.

In localities where the water supply is abnormally warm, a stop bath is recommended to be used between the developer and the hypo. Such a bath may be prepared by using chrome alum, one pound to one gallon of water, and approximately 4 cubic centimeters of concentrated sulphuric acid. The films should be removed from the developing solution, rinsed vigorously and placed into this stop bath for a period of two to three minutes prior to placing them in the hypo bath. If this procedure is followed, it will be possible to wash the film in water of higher temperatures, as the hardening action of the stop bath on the emulsion will prevent its running or slipping in moderately warm water or hypo.

Too few films come out the processing room without scratches. These abrasions may be caused by careless handling or by crowding the films in the developing and fixing compartments. With the ordinary five-gallon solution compartment or tank, it is difficult to develop or fix more than four 14 by 17 films at one time without scratching. In exceeding this number, not only does it increase the risk of scratching the films, but also the danger of ruining every pair in which the emulsions adhere to one another.

Thermometer

The processing room thermometer should be large enough so that its calibration can be read with accuracy. It is important that it be weighted to prevent floating on the surface of the solutions as surface temperatures are not indicative of true temperature values. The thermometer should not be housed in wood for this not only causes error in readings but also because it absorbs the solutions and transmits them from one tank to another. Over a period of time this would cause contamination of the solutions. To avoid film scratches, this thermometer should not be allowed to come in contact with the films.

Timer

A reliable timer is an indispensable item for accurately timing the intervals or steps required in film processing. It should be sturdy and accurate with a range sufficient to allow the maximum developing time and a means of signalling when this interval is concluded. Electrical interval timers are recommended for those laboratories processing a great number of films each day, as these timers are so arranged that when the current is turned off at the alarm, the timer automatically resets itself to a predetermined setting.

Drying Equipment

Film drying equipment is usually of the open rack type and located most conveniently for processing room procedures, or it may be of the forced draft type wherein the films are placed in a separate enclosed compartment and dried by heated air forced down over them. In either case, wet films must not be placed above films which have started to dry as this will cause spotting of the lower films. As mentioned before, forced draft film driers, when placed in the processing room, may be used as a means of ventilating this room.

Pass Box

In most laboratories a pass box is not only a convenience but a necessity, particularly in those laboratories where the darkroom entrance is some distance from the x-ray equipment, or where and when it is necessary to make a series of exposures. In many cases a pass box, particularly in a small laboratory, will eliminate the necessity for a lead-lined protective box.

Pass boxes are usually mounted in the wall to permit transfer of loaded cassettes and other materials from the film processing room to the outside and vice versa, without leakage of light into the processing room. Thus the work proceeds without interruption. These boxes usually have two separate compartments, one marked "IN" and the other marked "OUT," lined with sheet lead for x-ray protection and with a corrugated bottom to facilitate the passage of cassettes. The doors, both on the outside and inside of these pass boxes, are automatically interlocked to exclude light from the processing room. That is, when a door outside the processing room is open, the opposite door, or the one inside the processing room, and on the same side of the pass box automatically locks, thereby preventing white light from entering the processing room, Figure 183.

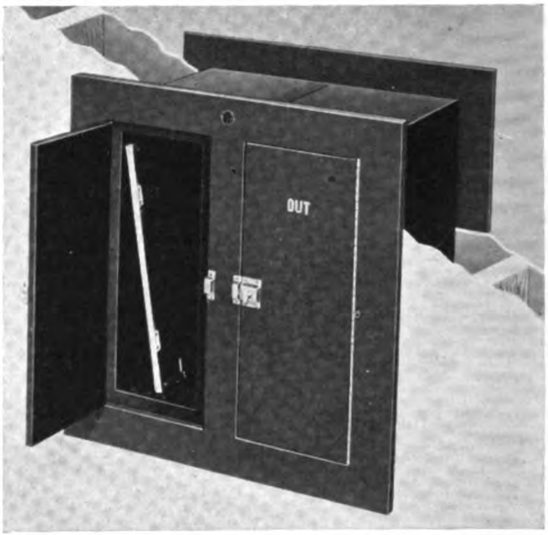


FIG. 183. Pass box.

There are many other accessories to facilitate handling and general procedure of film processing. A film corner cutter will quickly and uniformly round the corners of the radiographs so that they may be filed easily. Protective darkroom aprons will prevent soiling the clothing due to splashing of liquid chemicals; a tank cleaning brush and suitable wooden paddles are almost a necessity, as it is important that the tanks be thoroughly cleaned when chemicals are replaced and a special brush designed for this purpose makes this cleaning job a simple matter. The wooden paddles can be and should be used to stir solutions daily, due to different temperature layers that might exist in the developing solution and to the natural settling of the various chemicals which compose a developing solution. When it is impractical to have a drier in the processing room or to make necessary air vent connections for ventilation, small and practical motor-operated ventilators are available. Their installation is relatively simple. Properly ventilated processing rooms make the operators' work easier and more comfortable.

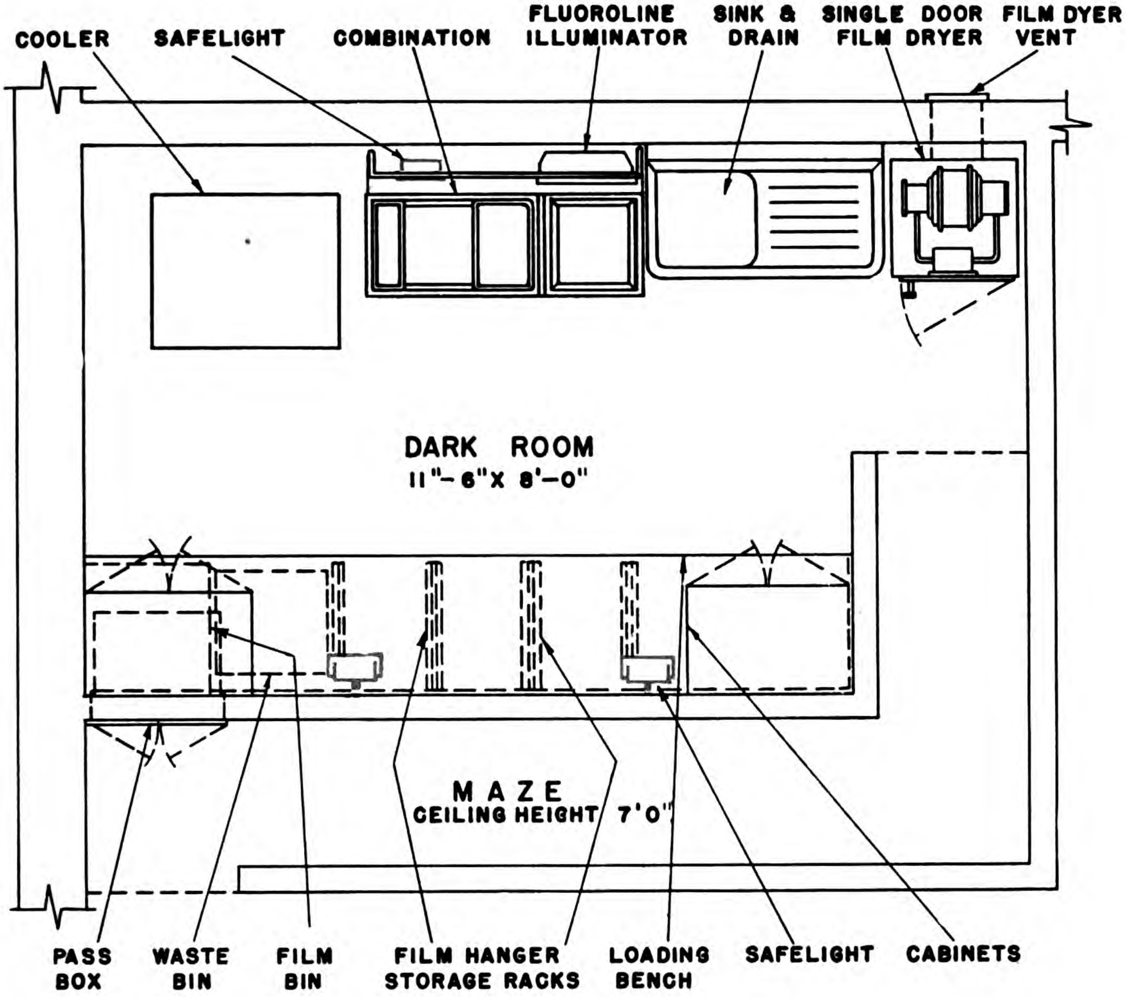


FIG. 184. Typical processing room layout.

Figure 184 shows a typical processing room installation utilizing a space 11 feet 6 inches by 8 feet 0 inches. It will be noted that this processing room requires a relatively small space, and with a small additional space a light-excluding maze could be constructed for practical and convenient operation. This installation is divided into two areas: the dry side and the wet side. This division of working areas tends to minimize danger to films and intensifying screens when loading and unloading as there is ordinarily little likelihood of moisture getting from the wet side of the room over to the dry side.

Recently improved formulae have been made in film-processing chemicals. These are of the so-called "speed" types. The developer, some of which is furnished in powder form and others which are liquid concentrates, allows for a shorter developing time and, in most cases, has a longer working life than the so-called "standard" chemicals. Figure 185 represents the time curve for these speed developers as compared to regular developer. Figure 186 is a chart showing the number of films that may be processed in these speed developers and the relative time change in development as the chemicals age. Figure 185, Curve A, shows processing times using reduced voltage and longer development with speed developers.

The speed hypos are faster in action than the standard types and apparently have a much longer useful life, Figure 187.

All developer and hypo as used in the x-ray processing room will stain clothing. Stains caused

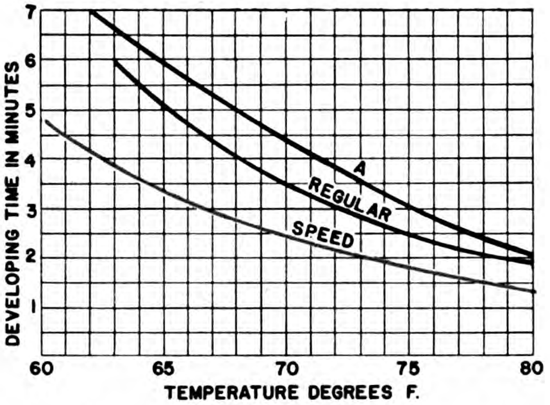


FIG. 185. Time curves, speed and regular developer.

by developer may be removed by the usual laundering process or by soaking in a weak solution of Linco or Clorox. Any stains remaining after laundering are nearly always caused by the fixer solution or other chemicals. Stains caused by the speed fixers become more and more pronounced as the fixer is used. This is due to the fact that it is metallic silver that is causing the stain, and the staining action is increased as more and more silver is removed from the unexposed parts of the x-ray film and transferred into the hypo solution. These stains may not become evident before the clothing has been laundered, but if any are present the usual laundering process will only make them worse. These stains are brown in color and usually have a sharply-defined border that is darker than the central area of the stain. Stains are easily avoidable, and while they can usually be removed without much difficulty, it is nevertheless easier to prevent them than it is to remove them. It is therefore desirable to wear an apron while processing the films, and since many fixer stains probably occur through careless handling of wet films, it is also highly desirable that films when removed from the fixer be thoroughly rinsed before being viewed.

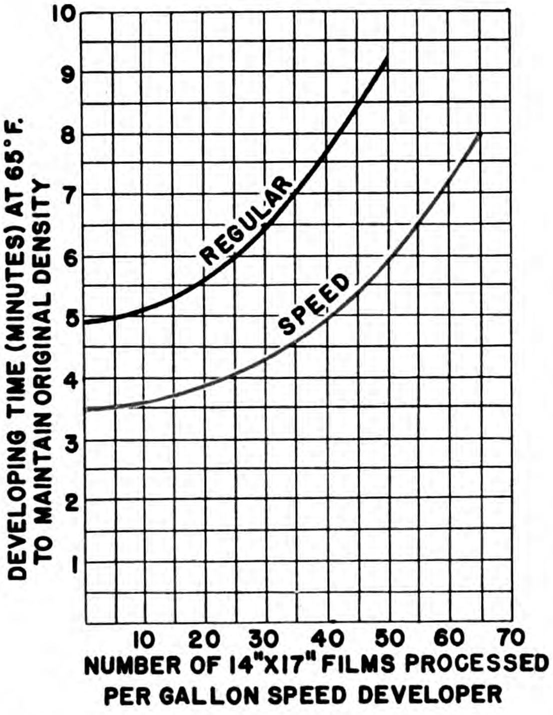


FIG. 186. Life curves of speed and regular developer.

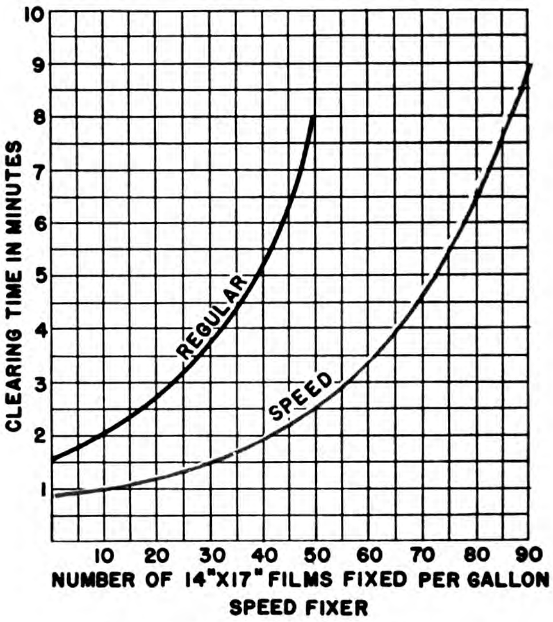


FIG. 187. Life curves of speed fixer.

Hypo stains on linen or cotton clothing can usually be removed with a 7 per cent tincture of iodine solution followed by the application of a saturated solution of sodium thiosulphate (ordinary hypo).

These two chemicals are readily obtainable in most localities. To remove fixer stains, first slightly dampen the stained areas. Unlaundered clothing should be thoroughly rinsed in clear water to remove dried fixer from the cloth and should be wrung out almost dry. Then apply a drop of iodine to each stain so that the stain is completely covered by the iodine. Use a piece of heavy paper to prevent iodine from soaking through the garment on to the table top or on to unstained areas of the clothing under those being treated. Allow the iodine to set a few minutes on the stain until it turns very dark and completely conceals the fixer stain.

Next apply a few drops of the saturated hypo solution to the iodine stain. In a few minutes the iodine stain and the fixer stains will have disappeared. Should any stains remain, repeat the treatment after first thoroughly rinsing the hypo from the garment with clear water, but this time allow the iodine to set about ten minutes on the stain before applying the hypo solution.

When numerous fixer stains are present, time can be saved by soaking the entire garment in a pail half full of hypo solution to remove the iodine. After concluding the treatment, rinse thoroughly in clear cool water.

Failure of this method to remove all stains is usually a definite indication that those stains still present are not caused by the fixing solution.

Loading of Films

Definite procedures apply to the opening of a film box which must be observed to avoid desensitized areas on the film and the resulting "crescent" marks, due to careless handling. Without removing the films from the box, the corrugated paper is first removed, then the red and black outer paper, by pulling their respective flaps. The front cardboard should then be placed midway in the packet so that it will act as a stiffener and eliminate warping.

When removing a film for loading cardboard holders, the black paper which encloses the film should not be removed, but placed with the film in the holder. This minimizes the possibility of fogging the film if the cardboard holder is not light-proof. When loading a cassette, however, the operator must be sure to let the paper fall away from the film. This is accomplished by taking the film out with the right hand, separating the film from the paper with the left hand, yet holding both until the film has turned 180 degrees. The paper should then be allowed to fall away from the film, thus minimizing friction and static. If there is difficulty in replacing the cover on the film carton, the sides should be pressed inward; this releases the air and allows the cover to fall into place.

Developing and Fixing

The developing and fixing solutions, unless used at par strength and according to prescribed time and temperature, are possible causes of more darkroom trouble than any other factors. Before discussing the reactions caused by old and stale chemicals, improper temperatures, contamination, etc., the following résumé is given of what actually takes place in these chemicals when a film is processed.

When an x-ray film is exposed to x-rays, the arrangement of the silver salts in the emulsion is changed, and instantly a chemical transformation in the emulsion takes place.

The stream of x-rays striking the silver crystals shatters these crystals, the amount of these rays governing the depth of the disturbance. Were it possible to examine one of these silver crystals as it is exposed to x-rays, we would see that it is broken up, and that the force generated by this shattering has partially broken each of the many crystals surrounding it. As an analogy, let us consider the bowling alley. When the head pin is struck by the rolling ball, it will fall, knocking over its neighbors until its force is spent. The angle of impact determines the number of pins downed. A beam of x-ray entering the film emulsion at an angle may strike a crystal on its edge. As little resistance is offered here, the beam continues through other crystals until its force is spent. A path of destruction has been left along the line of direction taken by the beam. The extent of disturbance of the crystal structure will be apparent when the effect of the developing chemicals is described.

The nature of the chemical change is not definitely known. However, it is apparent that a reduction of the silver salts to metallic silver is started by the x-ray exposures. A complete reduction is necessary and is brought about chemically by the developing bath.

The Developing Process

Chemicals which have the power to reduce silver salts to metallic silver must be used. Only a few of the many reducing agents are delicate enough and controllable enough to be used with x-ray films. Hydroquinone and metol are the most common reducers or developing agents in use today. It has been found that in x-ray developer both of these agents are indicated. Although either will act alone, they have certain characteristics unfavorable to x-ray emulsion unless they are used in combination.

Metol as the only reducing agent in a developing bath would produce very soft warm blacks in the negative, while hydroquinone alone would produce cold tones and harsh contrast. From this may be seen that if either is used alone, the fine middle tones so important in x-ray negatives would not be obtained. However, a combination of these two agents produces the different steps or gradations between the soft and contrasting tones, bringing out the best in each.

To obtain the correct tone scale in a radiograph, it is found that more hydroquinone than metol is needed; other ingredients must also be entered to prevent the hydroquinone from destroying the warm soft tones produced by metol. Potassium bromide is used for the purpose, as it has excellent restraining action on the hydroquinone.

Reducing agents combine readily with oxygen, causing oxidation. This would weaken the reducers rapidly and shorten their period of usefulness if another chemical acting as a preservative were not added. Sodium sulphite has the property of absorbing oxygen and is used in the developing bath to protect the reducers and prolong the life of this bath. Sodium sulphite plays no active part in the developing process, acting merely as a preservative.

Hydroquinone and metol inherently travel and act at express train speeds, *and must reach the most remote sections of the film to work on the x-ray exposed silver salts.* Like the express train, however, they must have a track and this is provided by sodium carbonate. This alkali has the property of preparing the right of way for its quick acting chemical companion. Its action is that of swelling the gelatine in which the silver salts are suspended, so that the reducing agents may reach and act on the exposed silver salts with a minimum loss of time. The amount of sodium carbonate in a developing bath controls the speed of the developer.

An exposed film is placed in the developing solution and the chemicals at work are observed. Some of these observations can be assumed as being made with the aid of a microscope.

The film in the hanger is slowly lowered in the developing solution and many small air bubbles clinging to the surface of the film are noticed. These bubbles keep the chemicals away from the emulsion, but by quickly raising and lowering the film a few times, the bubbles are brushed off and rise to the surface of the developing bath.

When coming in contact with the film surface the sodium carbonate starts to swell the gelatine, enlarging the pores and laying a track for the reducers. Several seconds pass before a change in the gelatine is seen. This interval is known as a latent period. Then it is noticed that the gelatine is gradually changing in appearance. The film surface is no longer smooth and even, but irregular, covered with innumerable small round domes, and there are tiny holes in the valleys made by these raised sections. Into these holes the chemicals enter as the alkali breaks down the wall of gelatine around the objective, the exposed silver salts. The reducing agent attacks the partially reduced salts.

The breaking or shattering of the x-ray exposed silver salts has been explained. If these salts had not been broken up, the developing action would be lengthened, as it would be necessary for the reducers to do all of their work from the outside of the film. However, as each small bit of exposed crystal is fractured, the reducers work rapidly from both inside and outside each crystal.

The life of the reducers is short, and is comparable with the human blood stream, in which the white corpuscles are destroyed while fighting foreign invaders and are carried away from the scene of action by the blood stream which also brings fresh agents to the front. The reducing chemicals in the developing process are destroyed as they do their work and are washed away by the solution, allowing fresh forces to complete the reduction.

The temperature of the developing bath controls the time of development. As the temperature is raised, the alkali works faster; as the temperature is lowered, it is retarded.

Three factors control the life of a developing bath, viz., its temperature, age, and the amount of work it has done. Developer may become exhausted from too much exposure to light and air. When not in use a cover should be placed over the developer compartment of the tank. It is recommended that reserve developer be kept in dark, stoppered bottles filled to the cork.

As films are removed from the developing solution, a measurable amount is carried into the rinse water. This loss of developer must be replaced so that the proper solution level is maintained. Generally fresh developer is added to accomplish this, but adding fresh developer actually accomplishes only one thing and that is proper maintenance of solution level.

More recently special refresher and replenisher solutions are used not only to maintain proper solution level in the tank, but to materially add to its useful life. In addition, such refreshers and replenishers, when added according to manufacturer's directions, aid in maintaining the original strength of the developing solution so that wide variations in developing time are entirely unnecessary in spite of greatly increased use or age. The use of such solutions will aid materially in maintaining radiographic quality.

The developing of the film is but the first step in the process of preparing it for viewing. The work done by the reducing agent must be preserved, and this stage of the processing will now be described in detail.

The Fixing Process

In somewhat the same manner, the various chemicals used in a fixing bath or hypo will be discussed, giving the reasons for their selection and explaining their actions on x-ray emulsion.

A hypo solution must do two things to the emulsion. First, it must stop development and must free the emulsion from all unexposed or unreduced silver salts. Second, it must preserve or tan the emulsion to prevent deterioration. The greater percentage of an emulsion is gelatine and, being animal matter, it will decompose and deteriorate if not properly treated.

One of the two active chemicals is sodium thiosulphate, commonly called hyposulphite or "hypo." This chemical is a solvent for the unreduced silver salt in the emulsion, and when fresh and at par strength its action is rapid. This chemical enters the emulsion of the film and dissolves the unreduced silver salts.

The second active chemical is alum. This is a tanning agent, and acts the same on gelatine as formaldehyde or tannic acid does on green leather. This chemical preserves the gelatine on the film, making it a permanent record. The hardening action of alum on the gelatine protects the emulsion, to a certain extent, from heat and scratches after the film has dried.

There are three other chemical agents also used in a hypo solution. First the acidifier, usually sodium bi-sulphite or sulphuric acid. This acidifier counteracts the alkali brought into the hypo bath when the film is transferred from the developing solution. Its action is to stop development. Upon removing the film from the developing solution, the greater part of the soluble material clinging to the gelatine will be washed away by a liberal rinsing in water. However, some of the reducing agents remain in the emulsion, and these are neutralized by the acidifier in the hypo solution.

Sodium sulphite is used in the fixing solution for the same purpose as it is used in the developing solution. It has no active part in fixing a film and acts only as a preservative, i.e., lengthening the life of the solution.

In some dry hypo preparations chromic acid is combined with the alum and is known as chrome alum. While chromic acid to a certain extent supplements the acidifier (sodium bisulphite), its main purpose is to make the hypo solution opaque to white light. Although the unreduced silver salts remaining in the gelatine after development are by no means as sensitive as they were before development, they nevertheless must be protected from white light, until the unexposed or unreduced silver has been removed from the gelatine. With a chrome alum type of hypo, white light may be turned on in the darkroom immediately after the films have been placed into the fixing solution, without danger of fogging the unexposed silver salts.

When a film is removed from the developing solution, the gelatine is like a sponge saturated with a solution of all the soluble materials which the developer holds. These last include the unoxidized reducers, the sodium sulphite, sodium bromide, and sodium iodide, and the oxidation products of that portion of the developing agent exhausted in the process, some of which may possess the character of dye. When a fully developed film is placed in a hypo solution, the acidifier in this solution immediately begins to counteract the alkali carried over from the developing tank and stops further development. As the gelatine is already swollen by the sodium carbonate in the developing solution, the many entrances to the silver salts are opened to permit the sodium hyposulphate to enter the emulsion and dissolve the undissolved silver salts.

While this action is going on, the alum is working on the gelatine, curing or tanning it, making it tough enough to withstand a reasonable amount of heat and ordinary handling. While the sodium sulphite is carried along with these chemicals, it has no action on the film or the emulsion itself, merely checking the exhaustion of the active chemicals.

The question of how long a film should be fixed is often brought up. A safe rule is to fix twice as long as it takes the unreduced silver (seen as a yellow creamy substance) to disappear from the film.

As the hypo solution ages it will slow down, until finally it reaches a point where the acid in the solution has become exhausted. Before it reaches this point, the quality of the radiographs will be affected. As the acid in the solution becomes weakened, the reducers in the gelatine, as carried over into the hypo solution from the developer, will continue their work. In experiments, it has been found that unless these reducers are stopped within a short time after the film is placed into a hypo bath, they will cause film stain. These stains, due to the insolubility of the silver salts, remain in the film and affect the quality of the radiographs.

Life of Developing Solution

The developing solution may become exhausted from age rather than use. However, it is simple to determine the efficiency of the solution by checking the quality of radiographs developed in it. The first sign of age in a developing solution is discoloration; it will gradually turn yellow and continue to dark brown. Developer in such a condition may produce stains and fog, and obliterate the contrast that might otherwise have appeared on the film.

Life of Fixing Solution

Hypo does not deteriorate rapidly unless films are processed through it. The length of time required to completely fix a film is a reliable check on the strength of the hypo bath. When it requires more than four times as long to fix a film as when the hypo was new, and at the same temperature, it should be replaced.

Preparation of Solutions

When mixing new solutions, it is important that the tanks be thoroughly **scrubbed.** If this is not done, some of the old chemicals will be mixed in with the fresh, and the process of oxidation will be set up at once, shortening the life of the new chemicals.

Always follow the directions written on the label of the developer or hypo container when mixing these chemicals. However, in cases of emergency, where it is necessary that the chemicals be prepared as quickly as possible, it has been found that the chemicals or powders may be dissolved in hot water (100 degrees F), using the tank or solution compartment for the mixing and then filling the tank with cracked ice instead of additional water. This ice will melt rapidly, cooling the solution to working temperatures, without ill effect on the chemicals or on the film.

Processing Room TROUBLE CHART

Condition	*Cause*
Gray films	1. Under-developed 2. Old developer 3. Developer weakened by dilution 4. Safelight fog 5. Developer too cold 6. Developer too hot
Stains	1. Improper rinsing 2. Improper washing 3. Developer exhausted 4. Developer contaminated 5. Hypo exhausted
Streaks	1. Developer not mixed completely 2. Under-developed 3. Dirty hanger clips
Static marks	Rough handling of under-developed films and/or cassettes

Condition	*Cause*
Crescent marks	Bending films while loading or unloading before development
Frost-like appearance	Incomplete washing after fixing
Corner marks	1. Wet or dirty fingers 2. Dirty hanger clips
Blank or opaque areas	1. Films sticking to each other or to side of developing tank 2. Films sticking to each other or to side of hypo tank
Reticulation	Too great a difference in temperature of developer and wash water, developer and hypo, or hypo and wash water
Light spots	Fixer or water on film before development
Dark spots	Dust, liquid, or powdered developer on film before development
White spots	1. Bubbles clinging to emulsion surface during development 2. Dry hypo on wet film while drying
Lack of contrast	1. Under-developed 2. Cold developer 3. Exhausted developer
Finger prints a. White	Hypo on fingers while handling dry, under-developed film
b. Black	Developer on fingers while handling dry, under-developed film
Multiple white specks	1. Dirty screens 2. Barium on cassettes, sheets, or table top.

Stereoscopy

In radiographic examinations, which may or may not include the various obliques and semi-laterals, there will often be parts of the anatomy that do not show to the best advantage. This is particularly true of skull, chest, and pelvic areas. As these regions are of considerable depth, the single, or so-called "flat" film does not permit the best conception of depth, nor does it reveal the relation of underlying structures. When such a problem exists, there is one device to which one may resort that will positively differentiate this depth of the object—*stereoscopy*. However, to achieve depth by the use of films requires the presence of optical illusion.

It is most interesting to observe that most persons possess, to a greater or lesser degree, monocular depth perception. To demonstrate this, one needs but cover one eye and look steadily at a photograph in a magazine or newspaper (not a sketch) or the motion picture screen, and there results a striking sensation of depth. Unfortunately this is radiographically impossible because, in the former case, the object is an image by virtue of reflected light and, in the latter, by virtue of transmitted energy. Thus, we must employ binocular vision for radiographic depth perception.

The unaided eyes determine depth according to two theories. One, by coordinated muscular activity of constantly changing the convergence of the axes of the eyes and accommodation, as one will focus on nearer and more removed objects. This is mentally interpreted, tempered by experience, as depth perspective with reference to the eyes. The other, when viewing an object, two slightly dissimilar retinal images are formed but the mind fuses them into one "mental" image. When two really dissimilar images are fused in this manner it is obvious that there cannot exist a mathematical coincidence. The resultant appearance of the third dimension is a true illusion.

Common to both theories is the matter of diplopia (double images). One need only point a finger to any object. Then, looking at the finger, one perceives two objects (homonymous); or, looking at the object two fingers (heteronymous). This is a very important observation and is the basis of the stereoscope, to which reference is made as "cross-eyed accommodation."

As the eyes are presented with slightly dissimilar perspectives, so may photographic and radiographic exposures be made, accounting for the interpupillary distance to give depth when viewing the films. For these exposures the tube is shifted from normal centering. The first film is made with the tube on one side of center and the second is made with the tube displaced from the other side of center by the same amount.

The plan of a simple box stereoscope with neither the familiar lenses nor mirrors is shown in Figure 188. This could be used for radiographs so taken with only two side-by-side illuminators.

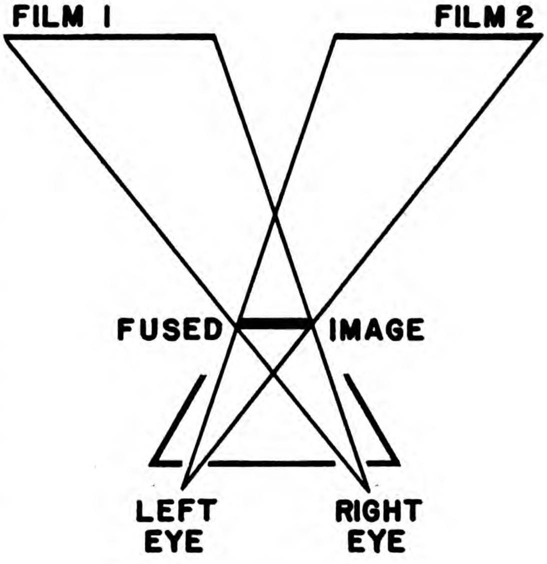


Fig. 188. Plan of box stereoscope.

in which each eye sees only one image and the fused resultant will have a virtual image at a slightly different eye-film distance from the original. Many individuals can accomplish this simply by crossing the eyes and allowing the two double images to fuse into a common one between the original two. This requires cross-eyed accommodation and, if used for any length of time, does produce eye strain. Relaxed accommodation is brought about by lenses and/or mirrors.

The Brewster stereoscope utilizes two lenses so each eye may see its proper film. Figure 189 shows how the result is obtained by using the two halves of a planoconvex lens placed symmetrically in front of eyes as base-out prisms. The result is a magnified image due to the action of the prismatic lenses. (This is not to be confused with the ortho-stereoscope which is used in conjunction with the 4 by 10 films taken in miniature for examination of the chest stereoscopically. This instrument employs reflection only, not refraction.)

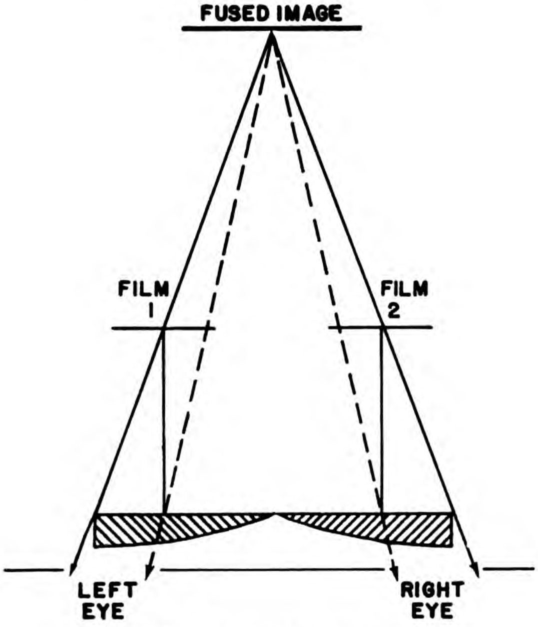


FIG. 189. Brewster lens stereoscope.

The Wheatstone stereoscope utilizes two mirrors so each eye may again see its proper film. Figure 190 shows how the result is obtained by using two front-surfaced mirrors at 90 degrees, bilaterally disposed in front of the eyes. The result is a fused image appearing directly behind the mirrors. In this case, because of a right-left reversal in looking into a plane mirror, the films must be axially reversed (turned over, not interchanged) in order to have the correct depth perspective.

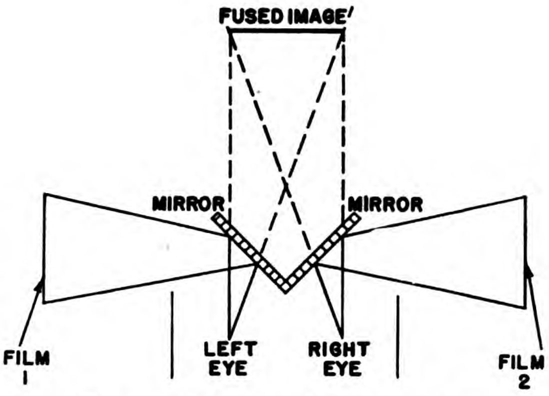


FIG. 190. Wheatstone mirror stereoscope.

One great advantage of the mirror type stereoscope (front surface mirrors particularly) is that the images in the mirrors are practically perfect, whereas the lens-images may be more or less faulty. (*Physiological Optics,* Jas. P. C. Southall, Oxford University Press, 1927.)

In the complete stereo-radiographic procedure there must be two films with slight, but similar, differences in their projections.

The tube is first aligned with the object and film, with the object or part centered to the film. It is very important that the film centers be coincident for these two exposures.

As previously mentioned, the tube is shifted to either side of center for these exposures, the amount of shift being a function of many things. The shift of the tube is to replace the two eyes from the standpoint of "looking" at the subject. If the shift is too small, there is but little departure from two "flat" films, the result giving extremely shallow depth; but, eyestrain is negligible and the images fuse with amazing ease. An extreme shift is really worse because then the dissimilarity of retinal images is too great and, as a result, they do not fuse because they represent two totally different projections. Figure 191A shows the normal projection of a solid (cube). Figure 191B represents a moderate monolateral shift and Figure 191C represents an extreme monolateral shift. Thus it is seen that, if the shift is too great, there results a

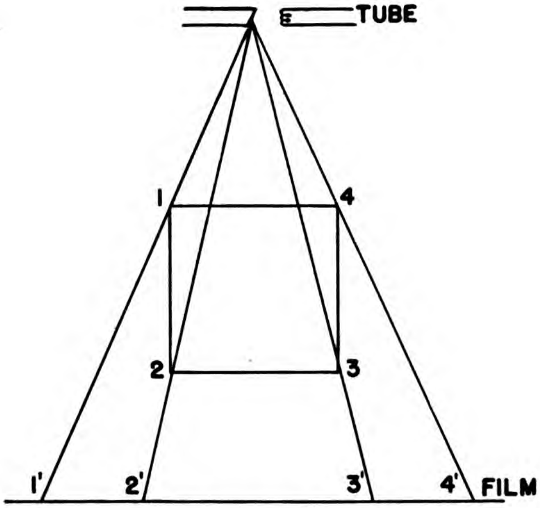


FIG. 191A. Normal Projection.

reversed order on one side. Under these last conditions stereoscopic vision is impossible because, effectively, one eye is seeing one side and the other eye is seeing the opposite side. Fusion of these two images is humanly impossible.

Figure 192 shows how Figure 191B appears as seen from above and indicates the equal dissimilarity of the bilateral projections; which, by crossed eyes brings out the true appearance of a solid, larger on the near surface and smaller at the distant surface.

The amount of tube shift is basically determined by the focal-film distance because of the difference in convergence of vision at different distances. Various authorities state that the shift should be everything from 2½ inches regardless, to a ratio of shift to focal-film distance of 1:9. A general statement cannot be correct because the shift ratio varies with distance. The old conception of a 25-inch usual viewing distance and an average interpupillary distance of 2½ inches (2½ inches tube shift) is reasonably correct. However, at say 30-inch focal-film distance, a total shift of 3 inches is found to produce some exaggeration of depth. If one exceeds this 1:10 ratio, resolved stereoscopy is difficult, if not impossible. A 1:9 shift, or greater, brings about that as depicted in illustration 191C in which one particular region or section will be found to stereo, but then all other regions suffer from doubling of image. For usual tube-table top distances, it has been found that a 1:15 ratio of tube shift will produce a more accurate perspective of the actual depth of the subject. Another desirable advantage is that 1:15 requires far less

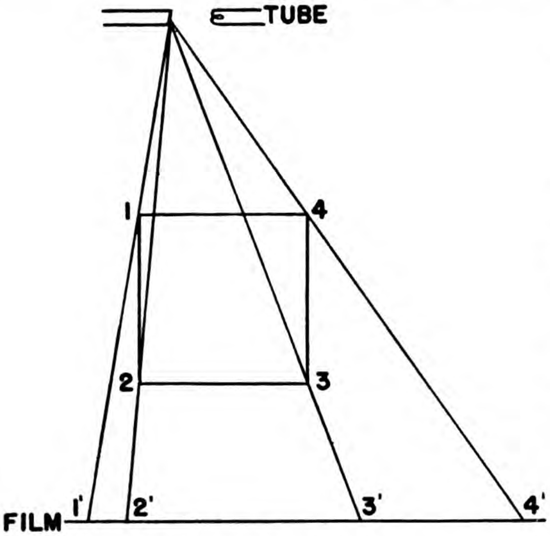


FIG. 191B. Small shift.

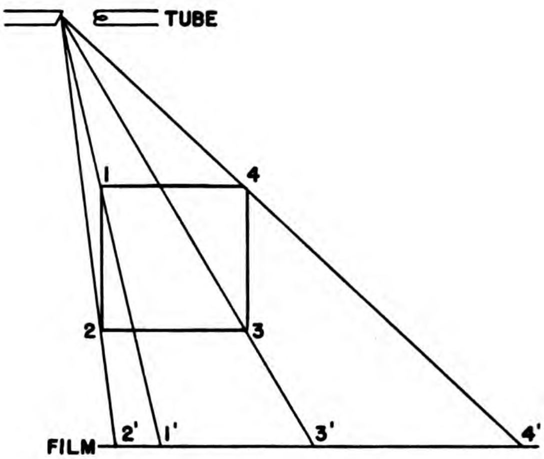


FIG. 191C. Great shift.

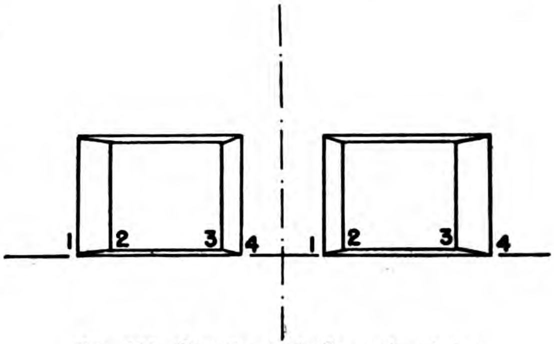


FIG. 192. Equally dissimilar pair, stereo.

optical accommodation than 1:10 or 1:9. This greatly diminishes eye strain when viewing many pairs of films. However, with distances in the order of 6 feet, 1:10 is used lest the result be too shallow due to the increased focal-object distance.

Also to be considered is the average, or mean, object-film distance with respect to the focal-film distance. As this ratio becomes smaller (a 36-inch chest compared to a 72-inch chest), the ratio of shift is accordingly increased; that is, the tube shift is reduced more than in proportion to a reduction in focal-film distance. Under no conditions should the shift exceed the mean diameter of the object; extremities, etc., in order not to create the condition as seen in 191C above. Of importance, too, is the distance from the lens or mirrors to the illuminators. As this distance is decreased, likewise the tube shift is also decreased.

All of the foregoing has contributed to a rather complex formula. For the sake of simplicity, it is illustrated in tabular form as seen in Figure 193. There are few occasions where the mirror-box distance will be less than 28 inches. A decreased tube shift to maintain sharpness of projection and a decreased mirror-box distance to regain depth is rarely employed. It will be observed that most radiologists using stereoscopes with adjustable illuminators will have them out as far as they will go which, incidentally, makes for easier convergent accommodation.

Focal-Film Distance	*Total Shift*	*Ratio*
25″	1-5/8	1:16
30″	2	1:15
36″	2-5/8	1:14
40″	3-1/4	1:13
48″	4	1:12
60″	5-1/2	1:11
72″	7-1/4	1:10
2 meters	8	1:10

Based on 28″ between illuminators and mirrors or lenses.

FIG. 193. Tube shifts.

For best visualization of superimposed structures, it is best to utilize a tube shift across the linear markings of the anatomy; viz., chest, up and down; extremities, crosswise; clavicle, up and down; skull either way—usually crosswise so the films will be erect in the view boxes. Joint surfaces and spine exposures should be made using up and down tube shifts.

Some operators complain of grid lines and unequal densities when employing a crosswise shift with the bucky diaphragm. This is usually corrected by "radiographically centering" the grid. In other words, the bucky adjustments should be such that the center of the grid is in the center of the table at the midpoint of the actual x-ray exposures. The presence or absence of this may be readily checked by attaching a lead letter to the underside of the grid center and another on the table-top center. The result of a light exposure with a film in the bucky tray should show the bucky letter's striations equally disposed on either side of center. Occasionally a cone or cylinder is used in stereoscopic procedures. In such instances the tube is to be so tilted as to direct the central ray to the center of the film in both cases. If one neglects to do this when using a small cone, it is possible to include two entirely different areas. Thus, the smaller the cone, the more accurate must be the alignment of tube, object, and film.

It is necessary to have screens of equal "speed" to insure equal densities. If not, a known correction should be applied to the slower one. Likewise the pair of films should be carried through the entire processing routine simultaneously, always handling both films together.

The film identification marker, if possible, should be placed on or attached to the table top or the top of the cassette tunnel. Thus it will bear identical space relations to the body, regardless of tube position and placing of the second film. This will also serve as a check indicating whether the films are placed correctly in the stereoscope or not. As seen correctly, the marker should always be on the far side of the subject. Some diagnosticians will place a lead letter on the upper portion of the area in question for a stereoscopic reference. This, of course, should then appear on the near side.

The proper way to place the stereoscopic films in the stereoscope is as follows:

Place the films side by side with the exposed side toward you; that is, place yourself in the position that was occupied by the tube during the exposure.

Superimpose the films and reverse them; that is, with the exposed sides away from you.

If the tube shift has been made up and down the films, place the left hand at the top of the films, and the right hand holding the films at the bottom. It will be at once apparent that the shadow image on one of the films is nearer the bottom than on the other film. That is, the shadow image on one of the films will be nearer the right hand, and on the other film nearer the top, or the left hand.

The film with the image nearest the right hand is then placed in the right hand box with the end in your right hand forward or toward you. The film with the image nearest the top, or your left hand, is placed in the left hand box with the end in your left hand forward or toward you.

If the tube shift is crosswise, superimpose the films as before.

Place the right hand at your right side of the films and the left hand at your left side of the films. It will be at once apparent that the shadow image on one film is nearer the right side of your right hand than the other.

The film with the image nearest the left side, or your left hand, is placed in the left hand box, with the side in your left hand forward or toward you. The film with the image nearest the right side, or your right hand, is placed in the right hand box, with the side in your right hand forward or toward you.

1. The film identification marker should be on the far side.
2. The greater sharpness should be on the far side.
3. If incorrect, the result is pseudoscopic, seen as antero-posterior instead of postero-anterior, or vice versa.
4. One film backwards, struggle for predominance of visual field.

It is well to remember that an opaque object will not stereo in itself. However, it may be located with reference to its surroundings, such as in the case of barium or a foreign body. On the other hand, translucents stereo beautifully, the most remarkable of which is the double-contrast colon—air insufflation after evacuation of a barium enema. The same is to be said of any such soft tissue procedure involving translucents.

If the object of stereo-radiography is in either the thoracic or abdominal viscera, it is well to have such accessory apparatus, or assistance to facilitate the exposure of the two films on sustained breathing; inspiration or expiration, as the case may be. On a stereo pair of chests, for instance, it is not impossible for the heart or some of the lung tissue to appear to be outside of the chest if part of the breath is exhaled between exposures.

There are many liberties one may take with suggested rules and tables for stereoscopy and still have an acceptable, or not too bad result which is possible only through the wondrous accommodation of the human optical system. This proves that there cannot exist a mathematical coincidence. Popular consensus does not concur in accepting stereoscopy as an optical illusion, which has made it a subject over which many heated discussions have been held. Regardless of why this phenomenon exists, there remains no question as to its effectiveness in aiding radiographic diagnosis.

CHAPTER X

Planigraphy

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Possible Applications 159

SUPERIMPOSITION of tissue structures is frequently a handicap in obtaining a radiograph that will show the most diagnostic information. Planigraphy offers a means of selecting a desired so-called "plane" or "layer" of tissue structure by blurring out tissues above and below the selected plane and thus, in many cases, the suspected lesion is more readily studied.

This chapter will explain in the simplest and briefest manner how the plane is obtained, how the thickness of this plane can be controlled, the technic factors and some unorthodox methods of positioning the patient to obtain the desired result.

How the So-Called "Plane" Is Obtained

As is well known to the radiologist and technician when taking a conventional radiograph, *movement of the x-ray tube, the film, or the patient during an exposure* will result in loss of detail sharpness in the radiograph. The greater the degree of the movement, the more pronounced the loss of detail sharpness; conversely, the less the degree of motion, the better the detail sharpness. No motion, of course, will result in the best detail sharpness. These facts form the basis upon which the planigraph works.

Figure 194 is a series of photographs of a planigraphic attachment showing tube and bucky

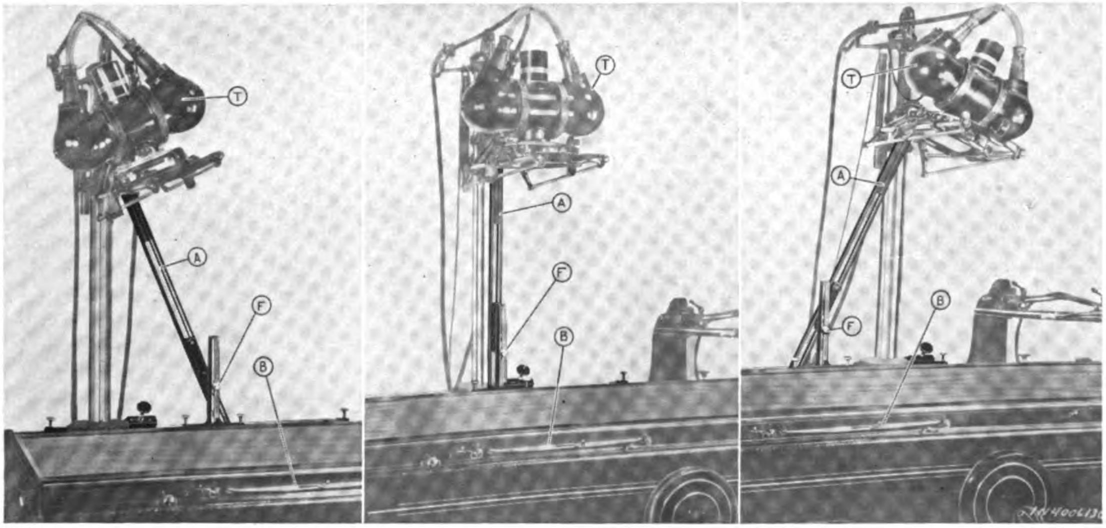


FIG. 194. Series of photographs of planigraphic attachment.

in three different positions, as the tube is moved from one extreme of travel to the other, lengthwise the table top. It will be noted that the tube (T) and bucky (B) are interlocked by means of an arm (A) and that this arm is made to pivot at a fulcrum point (F). In the left hand view, the tube is to the extreme left of the tube travel range, and the bucky to the extreme right of the bucky travel. In the center view, the tube and bucky have traveled to a point midway between the extremes. In the right hand view, the tube has reached the extreme of travel to the right and the bucky the extreme of travel to the left.

In analyzing these movements and referring to the above statements regarding the effect of motion on detail sharpness, it will be obvious that because the tube and bucky (or film) are caused to move during the exposure that detail sharpness in the radiograph will be lost. However, it will also be noted that there is no movement taking place (at least in theory) at the fulcrum point. Thus detail sharpness at the fulcrum point will remain comparatively sharp, whereas detail sharpness will be reduced above and below the fulcrum point.

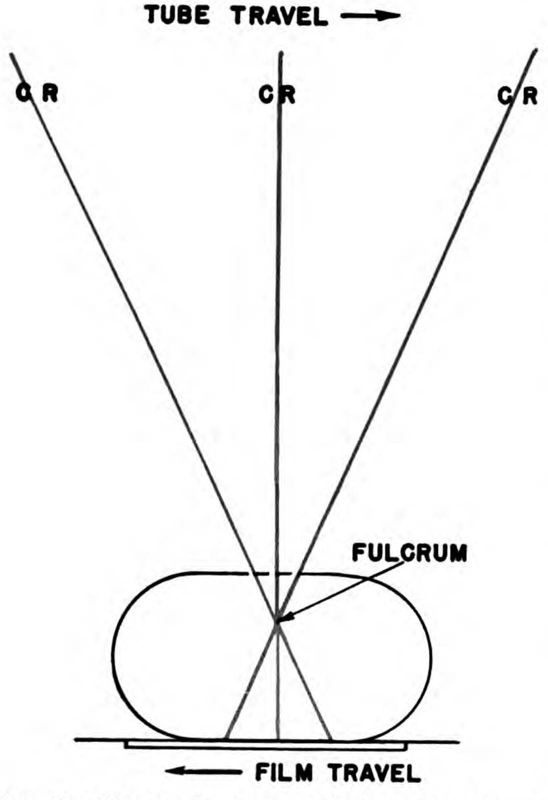


Fig. 195. Diagram showing central ray passing through fulcrum point.

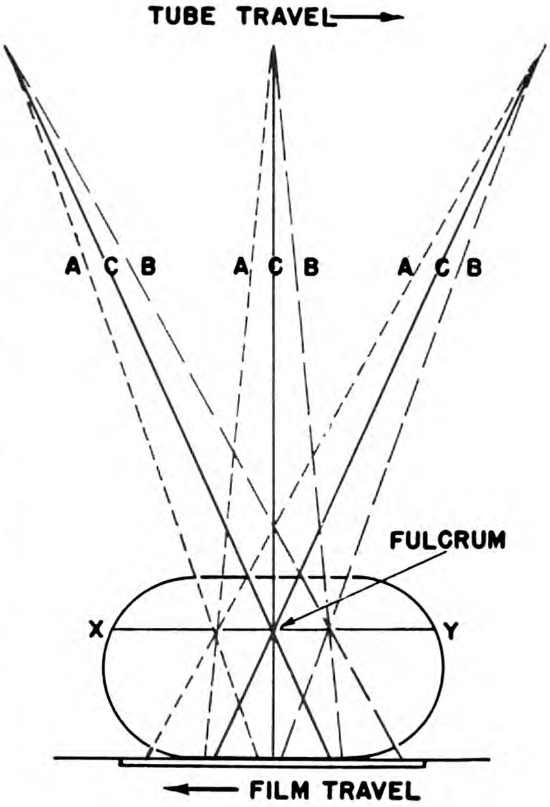


Fig. 196. Diagram showing primary rays passing through fulcrum point.

In Figure 195 it is shown that the central ray emanating from the focal spot of the tube passes through the fulcrum point at all positions during the movement of the tube and bucky.

If any given primary ray emanating from the focal spot of the tube is plotted, it will be noted that this ray will pass through a point on the same plane as the fulcrum point. In Figure 196, primary rays A, B, and C are plotted as emanating from the focal spot in three positions of the tube. Other primary rays emanating from the focal spot of the tube will duplicate these points. By connecting these points, a plane XY will be visible, along which plane the greatest detail sharpness will result because there is no motion (in theory) at the fulcrum point level. All levels above and below this plane will show less sharpness of detail, depending upon the

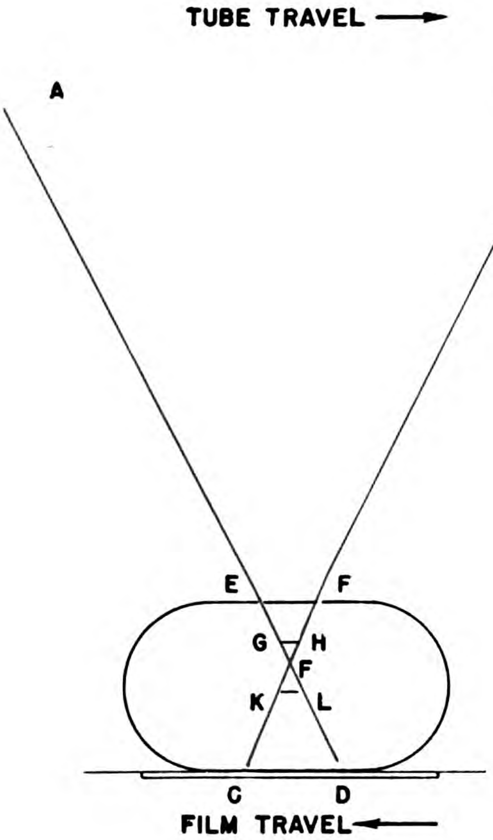


FIG. 197.

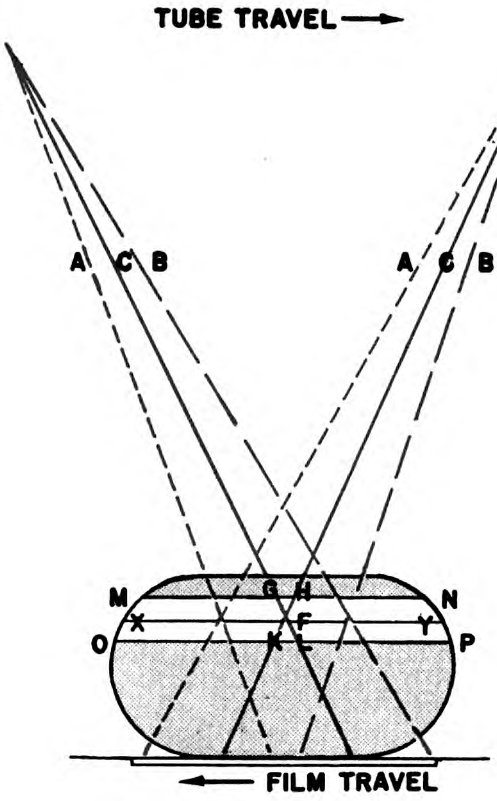


FIG. 198.

"degree of motion" of the tube and film.

In Figure 197, let the distance between the central rays AB represent the "degree of motion." The distance from E to F at the upper level of the object represents the greatest "degree of motion" in the object field, and detail sharpness would be at its worst. The line GH will show a lesser "degree of motion" and better detail sharpness, and the fulcrum level F the least "degree of motion," and the best detail sharpness. The line K to L, being the same length as GH, would be the same "degree of motion," therefore detail sharpness would be the same at levels GH and KL. The line CD would represent the greatest "degree of motion" below the fulcrum point and the detail sharpness would be worse than at KL.

In Figure 198, assuming that GH and KL represent the maximum "degree of motion" that can be tolerated from the standpoint of detail sharpness, then the structure between the lines GH and KL would have detail sharpness which, although not the sharpest, could yet be tolerated. By extending the lines GH and KL approximately parallel to the plane XY, a layer between MN and OP will result in which the visibility of structure is satisfactory.

Control of Thickness of Plane

The thickness of the so-called "plane" in which detail visibilty of structure is satisfactory can be controlled to a limited extent by several methods. Figures 199, 200, and 201 will aid in explaining these methods which can be controlled by the operator.

AT A GIVEN FOCAL-FILM DISTANCE, THE LONGER THE TUBE TRAVEL, THE THINNER THE LAYER WILL BE IN WHICH VISIBILITY OF STRUCTURE WILL BE SATISFACTORY.

In Figures 199 and 200, the focal-film distance remains the same, but the tube travel has been shortened in Figure 200 in comparison to Figure 199. If the length of the lines GH and KL, in Figure 199, represent the greatest

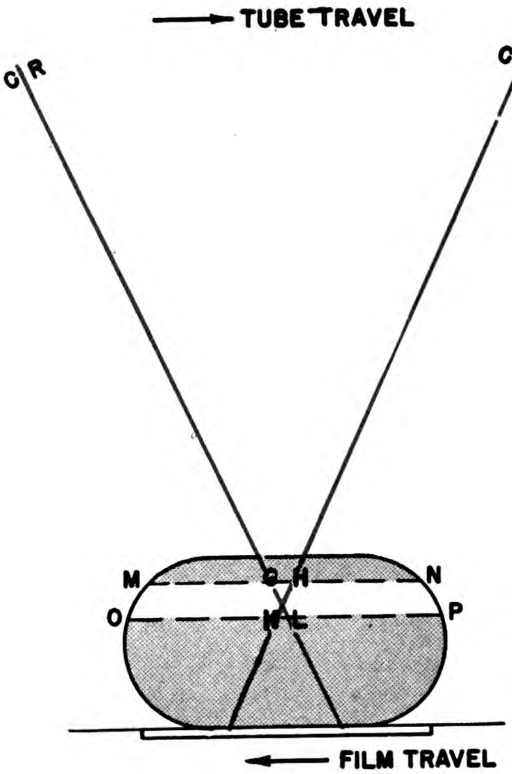


Fig. 199.

"degree of motion" that can be tolerated from the standpoint of structure visibility, then the lines of similar length, GH and KL in Figure 200, represent the same "degree of motion." The layer of structure between MN and OP, in which structure visibility is satisfactory, in Figure 199, is thinner than the layer between MN and OP, Figure 200, in which structure visibility corresponds.

THE SHORTER THE FOCAL-FILM DISTANCE AT A GIVEN TUBE TRAVEL DISTANCE, THE THINNER THE LAYER WILL BE IN WHICH VISIBILITY OF STRUCTURE WILL BE SATISFACTORY.

In Figure 201, the focal-film distance is shorter than the focal-film distance in Figure 199, but the tube travel is unchanged. The layer of structure in which visibility remains satisfactory is thinner in Figure 201 than in Figure 199.

Technic Factors

It must be remembered that in taking a planigraphic radiograph, usually a greater mass of structure will have to be penetrated by the x-ray

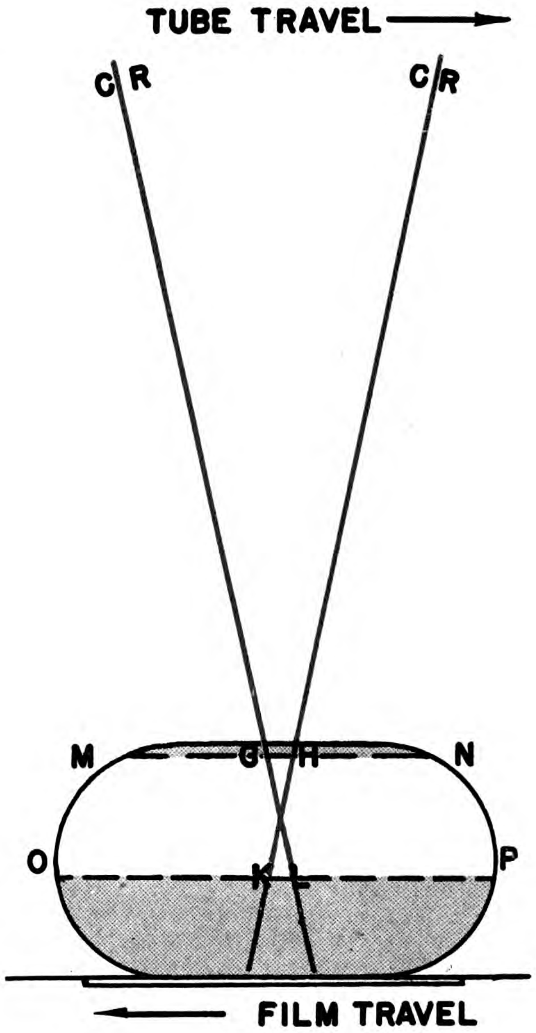


Fig. 200.

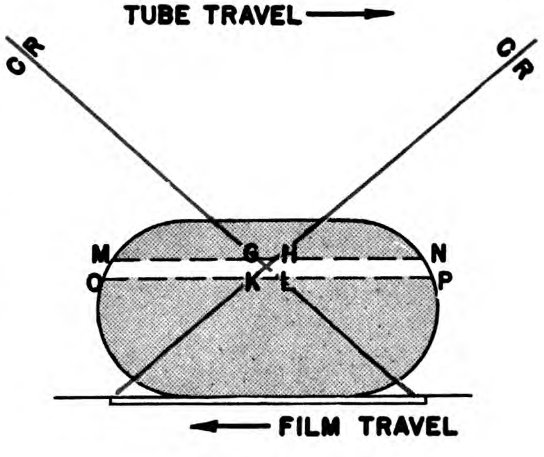


Fig. 201.

radiation, and for this reason the technic factors of milliampere-seconds or kilovolts peak used in planigraphy must be increased over that used for a conventional radiograph of the same part. In order to control tube travel, it is usually necessary to employ a longer time of exposure and a correspondingly lower milliamperage value than would be used for conventional radiography. Particularly does this apply when changing a non-bucky procedure to one employing the Potter-Bucky diaphragm. The lower milliamperage value also permits the use of small focal spots which is equally as desirable in planigraphy as in conventional radiography.

Usually a time of 1 second is as fast as the operator can manipulate the tube travel, but it can be moved as slowly as necessary to cover the complete tube travel distance in any time longer than 1 second. For radiography of the chest, the mass of structure may be the same or only slightly more than for a conventional radiograph of the same patient. For example, if a 500-milliampere unit is being used with a rotating-anode tube, a possible chest technic to take a conventional radiograph could be:

> Large focal spot, no bucky, 500 milliamperes, 1/20 second (25 milliampere-seconds), 72-inch distance, 50 kilovolts peak.

In using the planigraph on this same patient, the technic could be:

> Small focal spot, with bucky, 25 milliamperes, 1 second (25 milliampere-seconds), 40-inch distance, 50 kilovolts peak.

Another example, using a 200-milliampere unit could be:

> Large focal spot, no bucky, 200 milliamperes, 1/20 second (10 milliampere-seconds), 72-inch distance, 62 kilovolts peak for a conventional radiograph.

A planigraphic technic for the same patient could be:

> Large focal spot, with bucky, 10 milliamperes, 1 second (10 milliampere-seconds), 40-inch distance, 62 kilovolts peak.

An example of a lateral lumbar spine technic on either a 500-milliampere unit or a 200-milliampere unit, using a rotating-anode tube or a stationary-anode tube could be:

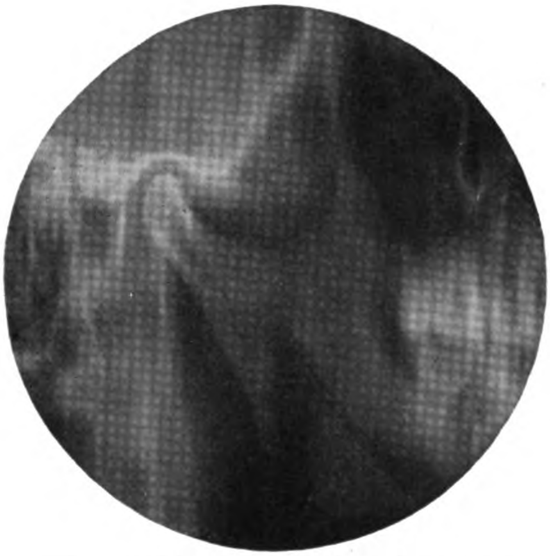


FIG. 202. Temporo-mandibular joint taken with planigraphic attachment.

> Small focal spot, with bucky, 50 milliamperes, 6 seconds, 36-inch distance, 76 kilovolts peak

for a conventional radiograph. For this area it may be found necessary to increase the kilovolts peak value 4 to 8 kilovolts peak for planigraphy.

Positioning

In positioning the patient for many of the planigraphic procedures, it is not necessary to

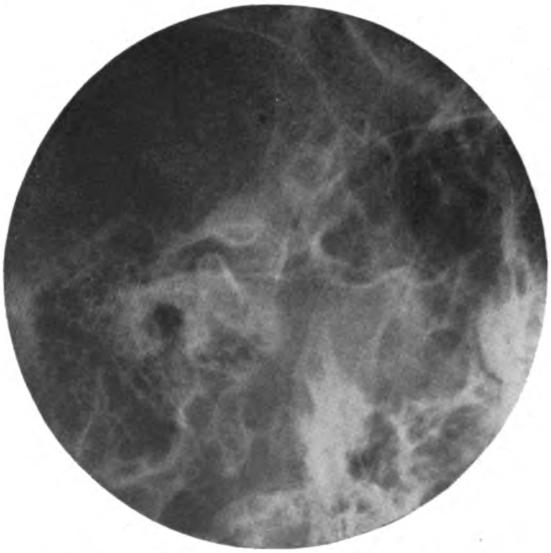


FIG. 203. Temporo-mandibular joint taken in the conventional manner.

tilt the tube or angle the patient to eliminate superimposition of structures. For example, in taking a temporo-mandibular joint in a conventional manner, it is usually necessary to tilt the tube or the patient's head to eliminate superimposition of the other temporo-mandibular joint. This is not necessary in using the planigraph. The patient's head is placed in a true lateral position and with the fulcrum point placed at the desired level, all structures on either side of the fulcrum point will have lost their detail sharpness and only that joint on the level with the fulcrum point will be clear, Figures 202 and 203.

A true postero-anterior radiograph of a sternum is not possible to obtain without the use of a planigraphic procedure because of the fact that the spine would be superimposed over the sternum and, because of the greater opacity of the spine as compared to the sternum, the energy necessary to penetrate the spine would be excessive for the sternum. This problem of superimposition and the necessary penetration for the spine remains the same when using a planigraph if the patient is placed in the conventional position. In planigraphy, tissues of greater density which lie exactly parallel to the tube travel are not entirely blurred out by the movement of the tube and film. By positioning the patient crosswise the tube travel, the spine (which is of greater density than the sternum) will be superimposed for only a brief moment during the tube travel and will not have to be

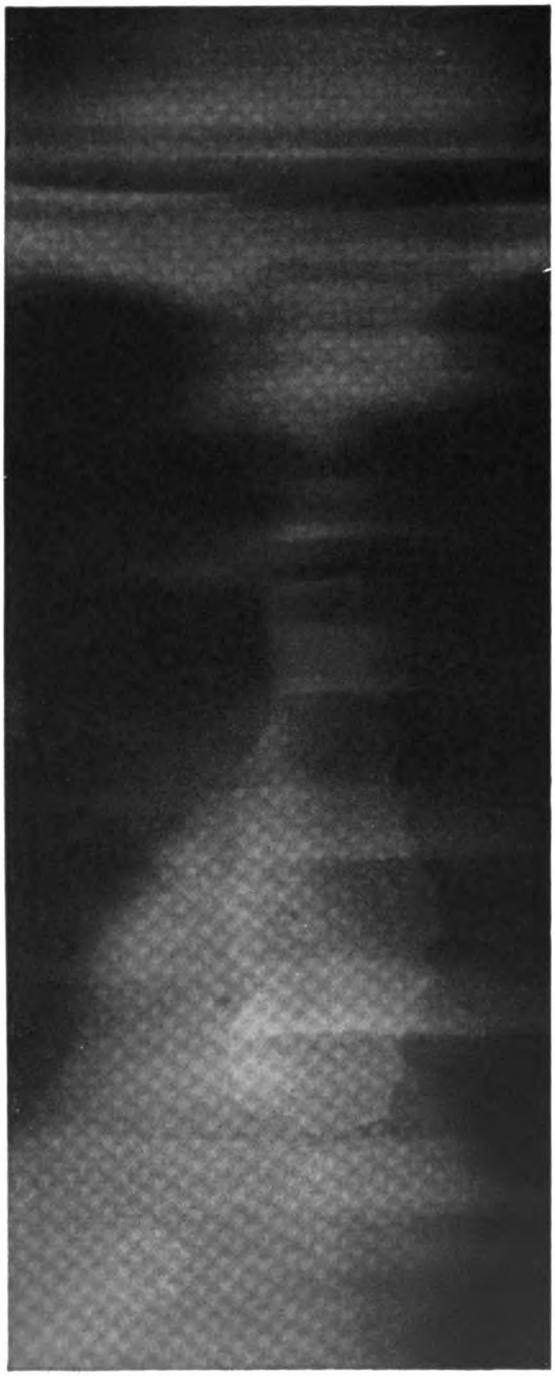


Fig. 204A. Sternum taken with planigraphic attachment.

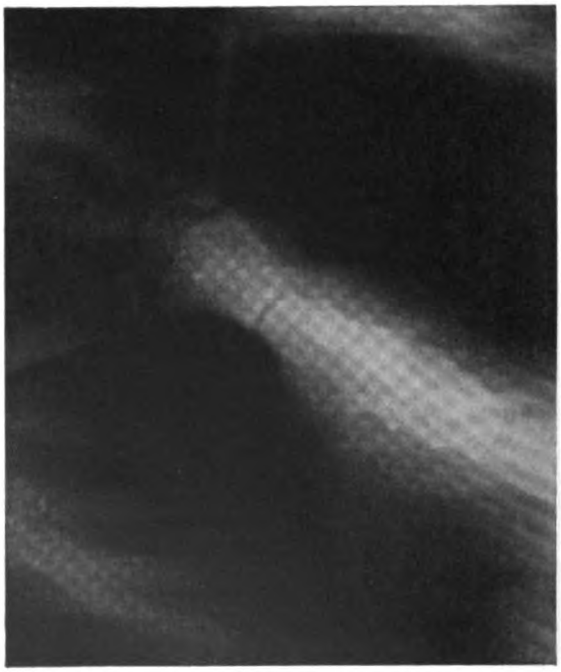


Fig. 204B

considered as far as opacity is concerned.

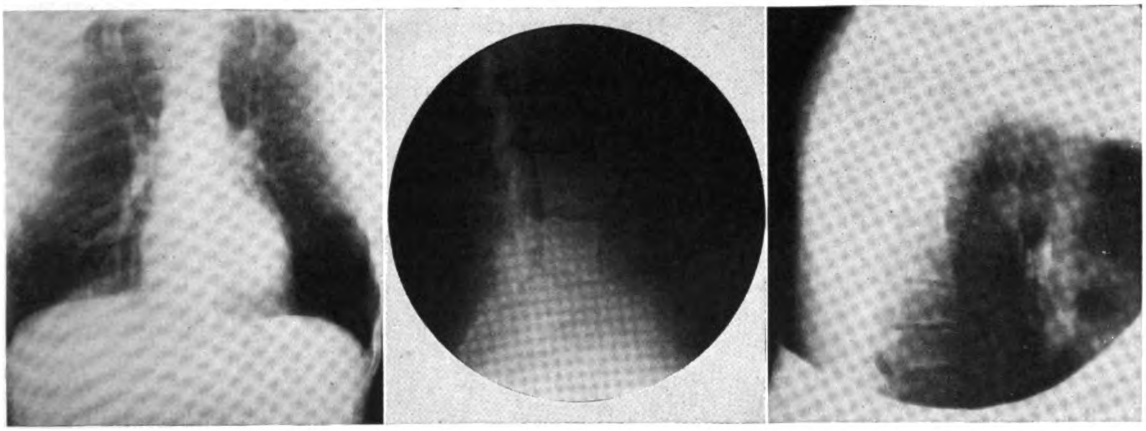
With the patient placed crosswise the tube travel as outlined, the sternum will be clearly visible on the resultant radiograph, but both posterior and anterior ribs will also be shown, Figure 204A, because the ribs will lie in a parallel plane to the tube travel and are thus shown on the radiograph. To overcome the problem of the greater opacity of the spine and to eliminate the ribs in taking a true postero-anterior sternum, using a planigraph, the patient is placed as close to the edge of the table as possible in the prone position, then by bending the body at the hips so that the patient's trunk lies at about a 25-degree angle across the table, both the spine and ribs will be eliminated, Figure 204B. The above information should be considered when similar problems are encountered in other regions of the body.

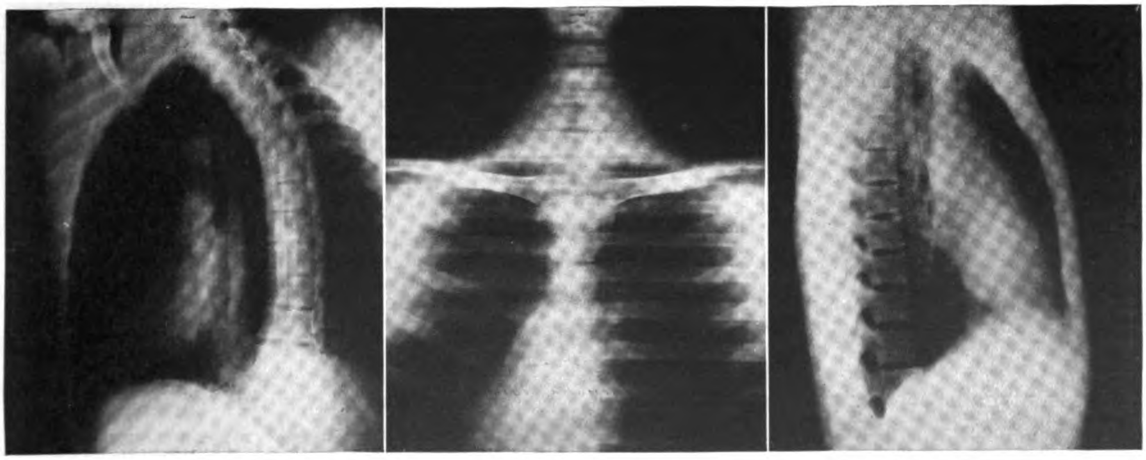
In taking a lateral lumbar spine, the fifth lumbar area being of greater opacity, the radiograph will show less density through the fifth lumbar region than through the region of the other four lumbar vertebrae. By slowing down the tube travel over the fifth lumbar, or speeding up over the others, the density will tend to be equalized throughout.

Possible Applications

Although planography has been chiefly used for the chest, many other regions can be radiographed to advantage.

The following are examples of radiographs made using a planographic attachment on different regions of the body.





Foreign Body Localization

The localization of foreign bodies is not an everyday occurrence in most laboratories, but when foreign body localization is called for, the technician usually finds very little authoritative information in the literature or elsewhere available as to procedure.

The simple method described here is a very satisfactory one, and is commonly referred to as the "single triangulation" method. It is not used in the case of lighter extremities where the usual two-view examination will suffice; nor for a foreign body in the eye. Its chief use is in the heavier parts, such as abdomen, spine, chest, etc.

The radiographic method only is given because it is more convenient and more accurate than the fluoroscopic method when using a conventional x-ray table. Furthermore, a permanent record is oftentimes of value.

The entire localization may be made with the patient lying on the usual combination table. The patient is placed either in the supine or prone position and, using the fluoroscopic tube under the table, the foreign body is located by means of the fluoroscope. The fluoroscopic field is only slightly larger than the foreign body. If the tube is properly centered to the fluoroscopic shutters, the position of the foreign body will be directly beneath the fluoroscopic image. With a skin pencil, a spot is made on the patient's body exactly in line with or over the foreign object.

A film is placed in position either with or without the bucky diaphragm, centering the mark on the patient's skin to the center of the film.

The radiographic tube is centered to the film and the focal-film distance carefully measured. The distance ordinarily employed is from 30 inches to 36 inches. This distance must be exact and it is advisable to check it more than once.

The distance is measured from the focal spot to the patient's skin at the point previously marked by the skin pencil.

An exposure is made using one half the time usually employed for regular work on this area.

Without disturbing the patient or film, the tube is shifted lengthwise the table a known distance 5 inches to 6 inches; the amount of shift must be exact.

After the tube has been shifted, a second exposure is made on the same film using the same technic.

Following processing, two images of the foreign body will be visible on the film.

If, during fluoroscopy, it was found that respiration caused motion of the foreign body, both exposures must be made under the same conditions (inspiration or expiration) as when the foreign body was located under the fluoroscope. Focal-skin measurement should be made under the same conditions.

The distance between the two images is carefully measured. This is best done by measuring from some point on the edge of one image to the same point on the edge of the other image. This distance is known as the "shadow" or image shift.

For example, assume the focal-film distance to be 30 inches, the tube shift 5 inches, the image shift 1½ inches, the focal-skin distance 20 inches. Using these figures, a geometrical construction is plotted according to Figure 205.

If a piece of paper over 30 inches long is available, the actual measurements may be laid out, and the readings taken direct, in which case the actual depth of the object is shown.

The drawing may be reduced a definite amount, such as one half, in which case all findings must be multiplied by two to arrive at the correct values.

In Figure 205, A to B is 30 inches and represents the focal-film distance. A to C is 5 inches and represents the tube shift. E to B is 1½ inches and represents the shadow shift.

The position of the foreign body will be found at F where the line CE intersects AB. Measure

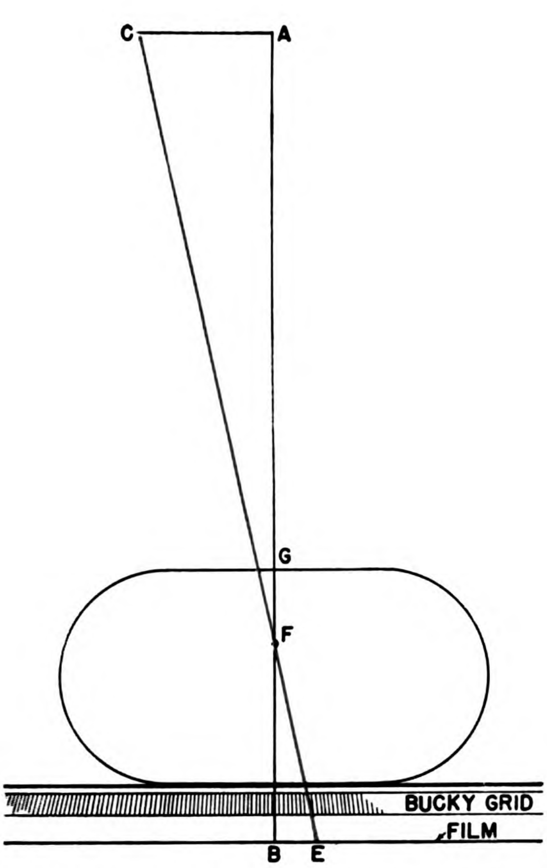


Fig. 205. Diagram illustrating single-triangulation method of foreign body localization (radiographic).

distance from A to F which is the distance from the focal spot to the foreign body (22-¾ inches).

The distance is deducted from the focal spot to the mark on the skin, AG, which is 20 inches. The distance of the foreign body below the mark on the skin is 2-¾ inches, GF.

If the foreign body is quite close to the side nearest the film, the shadow shift may be too small for accurate measurement when using a 5-inch tube shift. Either the patient should be placed so that the foreign body is nearest the tube, or the tube shift increased.

The accuracy of the localization will depend upon the care used in locating it fluoroscopically, and accuracy in measuring all distances.

It might be well to place a coin or other metal object in a book and, using the method above described, see how accurate a localization may be made. One or two trials of this type will make it much easier for the operator to make a rapid and accurate localization when the time comes to use it on a patient.

Figure 206 is a reproduction of a radiograph showing a foreign body following double exposure.

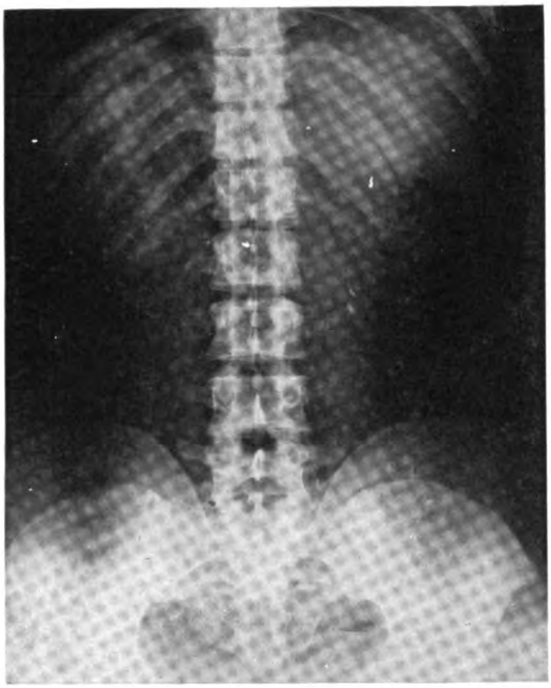


Fig. 206. Radiograph of foreign body preparatory to localization.

Summary

1. Place patient on table and fluoroscope for foreign body location.
2. Mark skin directly over foreign body.
3. Place film under patient, adjusting radiographic tube for desired focal-film distance.
4. Measure distance from focal spot to mark on patient's skin.
5. Make first exposure.
6. Shift tube and make second exposure on same film.
7. Measure distance of shadow shift.
8. Draw line AB.
9. Draw line AC.
10. Draw line BE.
11. Construct line CE.
12. Measure AF.
13. Deduct AG from AF.
14. GF is the distance of foreign body below mark on skin.

Fluoroscopy

The technician plays a comparatively small part in fluoroscopy. Aside from adjusting the technical factors for satisfactory fluoroscopic vision, and the general assistance to the diagnostician, little else is possible.

However, for general information, the following taken from the *National Bureau of Standards HB-20,* and the *United States Army Manual, The Recommendations of the International Roentgen-Ray Committee on X-Ray Protection* should be of value.

> "The following precautions and procedures shall be observed.
>
> "Eye accommodation preceding fluoroscopy. The operator shall allow his eyes to become fully accommodated to the darkness before starting a fluoroscopic examination. This may be done by remaining in a dark room or wearing fluoroscopic goggles provided with special dark lenses. At least five to ten minutes are necessary for proper accommodation of the eyes.
>
> "Failure to observe this rule will result in unsatisfactory fluoroscopic vision and will tempt the operator to increase the milliamperage, kilovoltage, or time beyond the recommended maximum value and thus expose the patient and, under certain conditions himself, to dangerous amounts of radiation.
>
> "Eye accommodation before beginning a fluoroscopic examination applies with particular emphasis to the use of head type fluoroscopes.
>
> "Use of x-ray protective devices imperative. X-ray protective devices, such as lead rubber gloves, lead rubber aprons, lead protected fluoroscopic chair, etc., shall always be used. The operator's unprotected hands, wrists, arms, or other parts shall never be exposed to the x-ray beam.

"Observance of focal-skin distance. For fluoroscopy the distance between the target of the x-ray tube and the patient's skin shall be at least ten inches. Greater distances are preferable since they reduce the likelihood of over-exposure and improve the fluoroscopic image. The intensity of the x-radiation reaching the patient's skin varies inversely with the square of the distance from the target of the x-ray tube. For example, the x-ray intensity at 10 inches distance is 4 times that at 20 inches distance, all other factors remaining the same.

"Use of filter as a standard practice. The best practice is to use a minimum of 1 mm. aluminum filter, or its equivalent, between the x-ray tube and the patient, particularly for fluoroscopy.

"Lowest possible current value advisable in all fluoroscopy. For fluoroscopy the milliamperage setting shall be as low as possible without sacrificing satisfactory fluoroscopic vision. Milliamperage shall in no case exceed 5 ma.

"Kilovoltage is set in accordance with the thickness and density of the body part being examined. For best vision, it shall be kept as low as possible, and although 100 kv is available in some installations, it is a rare instance that requires more than 85 kv. It is common practice to use not more than 3 ma at 85 kv for abdominal fluoroscopy; 3 ma at 70 kv for chest; 3 ma at 60 kv for extremities.

"Recommended procedures during fluoroscopic examination. During fluoroscopic examination make short intermittent exposures rather than long, continued ones. This practice allows the eyes to re-accommodate during the dark intervals and increases the visibility of the image. It reduces the amount of radiation the patient receives and prolongs the life of the x-ray tube.

"Restrict the size of the radiation aperture (shutter) to the smallest area necessary to cover the part being examined. This prevents needless exposure of other parts of the patient's body and improves the visibility of the fluoroscopic image.

"Palpation with the hand or other manipulation under the fluoroscope for setting of fractures, foreign body localization, or other such procedures should be kept to a minimum. Under no circumstance should an operator use any part of his body for fluoroscopic demonstration nor should he hold any cassette, medical or dental film in position during exposure.

"Tube ratings and maximum permissible exposure values. Consult the tube rating chart for maximum permissible time, kilovoltage and milliamperage which apply to your fluoroscopic tube. Never exceed these ratings.

"As a guide in determining the safe exposure factors for fluoroscopy or radiography, consult Figures 148 and 149, page 109, the tables of maximum permissible exposure values in milliampere seconds. Milliampere seconds are the product of milliamperes and total actual exposure time in seconds. In using these tables, the maximum permissible exposure time in *seconds* is obtained by dividing the milliamperes used into the value of milliampere seconds tabulated; as for example, if the milliamperes used are 5, and the permissible exposure value in milliampere seconds totals 1000 at a given filtration, kilovoltage, and distance, the milliamperage (5) is divided into the milliampere seconds (1000) which gives the time—200 seconds. This figure constitutes the maximum exposure time at such a voltage.

"The tables in Figures 148 and 149, which apply to both radiography and fluoroscopy, are based on operation at 85 kvp. When using higher kilovoltage, a reduced value *must* be used. When using a lower kilovoltage, an increased value may be used but it is preferable to employ the tabulated values and take advantage of any increased margin of safety. The maximum permissible exposure value in milliampere seconds for distances other than those given in the above tables can be determined by application of the inverse square law of light which is to the effect that the amount of radiation striking a given area varies inversely with the square of the distance from the target of the tube.

"For adjustment of these tables when using a kilovoltage different from 85 kv, the following percentage changes may be used:

KV.	*Change in Maximum Permissible Exposure Values*
100	Reduce by 25%
90	Reduce by 8%
85	No change
80	Increase by 10%
70	Increase by 35%
60	Increase by 80%

"The first table applies to all parts of the body excepting the head; the second to the head only, and is a reduction of approximately 25% of the values of the first.

"Since the effect of x-radiation is cumulative, be certain that the amount applied by you to the patient, together with the amount—diagnostic or therapeutic—which the patient may have received during the period of four weeks preceding, together with the amount which will be used for radiography during the course of your examination, does not in its combined total for any area, exceed the generally accepted maximum safe limits.

"For the user's information, the total filtration value heading each column of tables, Figures 148 and 149, is divided into inherent and external. The values of permissible milliampere-seconds still apply when this same total is obtained by a different division of the inherent and the external filter. The inherent is dependent upon the particular filtering characteristics of the tube aperture and any other permanently interposed filter.

"The values of these tables are based on:

1. The average output of a typical installation.

2. The average figure of 275 roentgens for a 'threshold erythema.'
3. A factor of 50% which is necessary to cover unpredictable variations in either of the first two factors.

"These values are intended to serve only as a guide and should be replaced by similar styled tables based on the actual measured output of the installation and the user's estimate of the value of the 'threshold erythema.'

"For assured safety, these tabulated values shall not be exceeded until replaced by the user's own values.

"Keep a record of exposure factors used during the examination."

During the past few years there has been an increase in the use of the stationary bucky grid in fluoroscopy. The effect of the grid in fluoroscopy is the same as in radiography, an increase in contrast, particularly in the more opaque areas. Its use makes necessary an increase in energy. It is preferable to increase kilovolts peak when practical, instead of milliamperes.

This increase is approximately 10 kilovolts peak when the grid is properly positioned. If the grid and screen are tilted crosswise the strips, increased filtration materially reduces the visibility of the fluoroscopic image. Because the distance from the tube focal spot to the screen is comparatively close, a focused grid will provide a better uniformity over a large area, but as the radiation aperture (shutters) is restricted, uniformity of the field is increased even when using an unfocused grid.

An increasing amount of radiography is being done with the fluoroscopic tube. Most of such work is gastro-intestinal, although valuable information may be obtained for other areas such as the spine, chest, heart. The use of the fluoroscope permits more accurate positioning for many areas, and the radiograph becomes a permanent record of the fluoroscopic image. This method may be particularly helpful when "out of ordinary" positions are necessary.

"Spot-film" radiography in general applies to fluoroscopic positioning, wherein a single film is taken of each position. That is, fluoroscopy is done between radiographs.

"Spot-film serial radiography" refers to taking two or more views of the object without fluoroscoping between.

In spot-film gastro-intestinal work, compression cones are employed to a large extent. When compression is used, the energy required for both fluoroscopy and radiography may be reduced considerably over that necessary when no compression is used. Technics therefore must be based upon compression.

Inasmuch as respiration affects the position of the stomach to a greater or less extent, the radiograph must be taken at the same period of respiration as was used in fluoroscopy.

Because the tissue thickness is ordinarily greater with the patient in the upright position for abdominal work, the energy required is greater than when the patient is either in the prone or supine positions.

Both single and double focus tubes are used for spot-film radiography.

If the rating of the x-ray tube is carefully followed, the double-focus tube adds nothing to tube life over a single-focus tube. In fact, for the combination of fluoroscopy and radiography, a single-focus tube having a focal spot size between 2.5 and 3 millimeters will give generally satisfactory fluoroscopy and radiography. When a double-focus tube is employed, the fine focal spot will give somewhat better detail, but the larger focal spot, usually 4.5 to 5 millimeters, used for radiography, detracts materially from the resultant detail. Bear in mind that the average focal-film distance, when using the fluoroscopic tube, is approximately 22 inches. The large focal spot in combination with this close distance is the reason for the loss in detail. Many observers feel, however, that this detail loss is not considered a handicap, in which case the double-focus tube does have the advantage of a smaller focal spot for fluoroscopy, and a higher radiographic rating.

As previously mentioned, the specific technic is based upon tube ratings.

The milliampere-second value for spot-film radiography ranges from 25 milliampere-seconds to 100 milliampere-seconds, 50 milliampere-seconds being a fair average. The kilovolts peak range is usually from 65 to 85 kilovolts peak.

Soft Tissue Radiography

Radiography of the soft tissues should be considered a most important part of routine laboratory procedure. Despite its accepted diagnostic value, however, this type of work is not in general use due mostly to a lack of understanding of the technical factors involved. In addition to this, there is a considerable variation in opinion as to what constitutes a soft tissue radiograph of the highest quality. *The object in view is to produce differentiation within the soft tissues and not merely an outline.*

In many instances a non-screen procedure is employed and referred to as soft tissue technic because the outline of soft tissue is visible. It is not unusual to have a soft tissue procedure described as one wherein the time of exposure has been reduced to one-half or one-third that ordinarily employed for a regular radiograph of the same region.

When such technics are employed, the results are bound to be disappointing because there is little or no differentiation within the soft tissue area.

Figures 207 and 208 of the lateral elbow region demonstrate the difference between a soft tissue outline and soft tissue differentiation. Figure 207 was made with a non-screen procedure while Figure 208 was made with screens using a technic adapted to this highly specialized type of work.

The areas which lend themselves best to this procedure are those with less opacity, all extremities, neck, breast, etc. Soft tissue differentiation as applied to the more opaque areas such as kidney and gall bladder have benefited particularly since the advent of the rotating-anode tube, but such areas do not lend themselves to the same degree of improvement because of their increased opacity and superimposition of under and overlying structures.

As previously discussed, a radiograph of any part of the body is a record of the various degrees of relative opacity within the area exposed. If all parts of the body were of the same relative opacity, then a radiograph would be of no value. However, the body is composed of tissues of various degrees of opacity, and visibility of structure on the film depends mostly upon the technical procedure. Some parts are more readily taken than others and allow for a considerable variation in procedure, while others require the maximum in technical skill and knowledge.

In general, areas which are considered less difficult to radiograph are those in which the difference in opacity in the various structures involved is quite marked. Parts which are con-

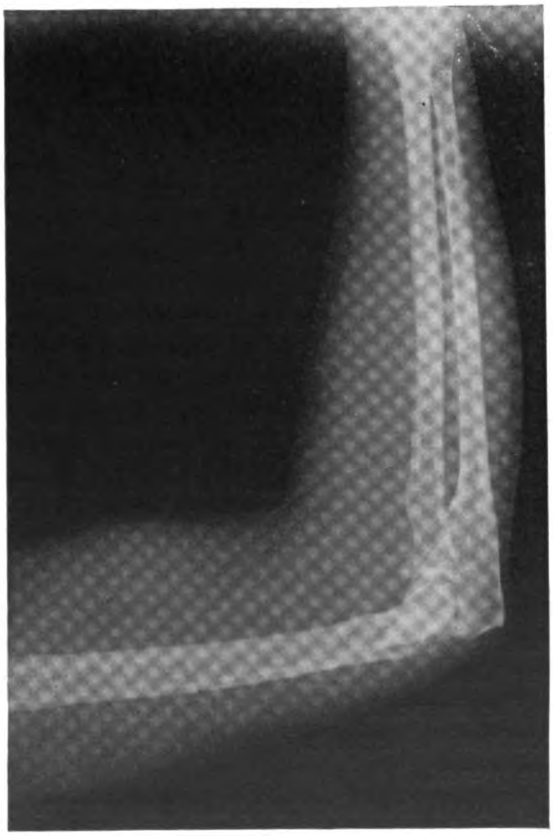


Fig. 207. Radiograph of lateral elbow without screens.

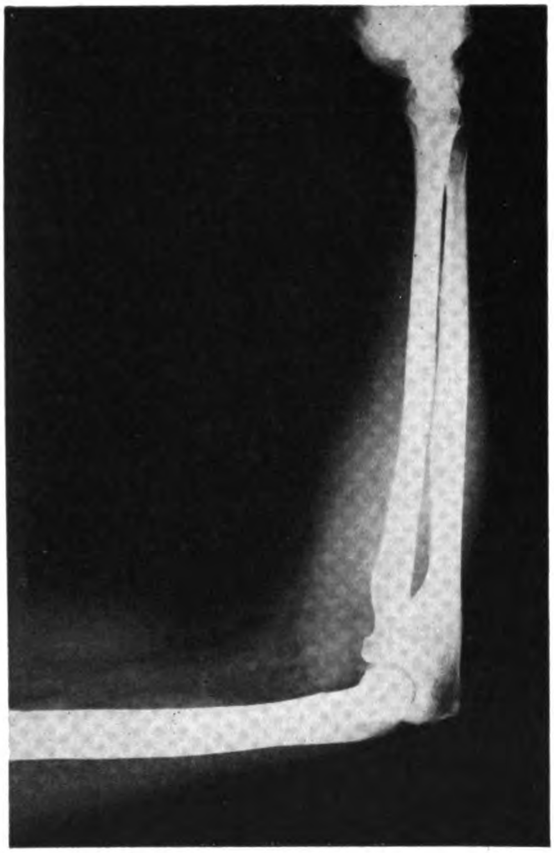


FIG. 208. Radiograph of lateral elbow with screens.

siderably more difficult to radiograph are those in which the difference in relative opacity in the various structures is very slight. Radiographs of early callus, early arteriosclerosis, soft tissue tumors, varicose veins, etc., comprise the latter.

The many factors which influence radiographic quality have been considered in Chapters VI and VII. The only difference in these considerations as applied to soft tissue radiography is that added emphasis must be given to some of them and, conversely, less emphasis to others.

As with regular radiography, maximum differentiation of tissue is realized only when the film shows both maximum sharpness of detail and maximum visibility of detail of the part or parts on which interpretation is centered.

The diagnostic quality of any radiograph depends on the degree in which these two essentials are present.

While it cannot be stated that maximum contrast is desirable in soft tissue radiography, considerably greater contrast is necessary than for any other type of radiography. In addition, radiographic density must be kept within a comparatively narrow range if maximum diagnostic quality is to be obtained. Thus, those factors affecting both contrast and density must receive primary consideration.

The fact that contrast and density are considered of first importance does not mean that sharpness of detail can in any way be disregarded. All factors affecting detail sharpness in general radiography must receive equal consideration in soft tissue radiography with the exception of intensifying screens.

Because of the technical procedures necessary in soft tissue radiography, intensifying screens are essential. Consequently, any loss in detail sharpness is reduced to that brought about by the use of screens.

The specific operating factors of kilovolts peak, milliampere-seconds, distance, are not only dependent on each other, but upon the equipment available.

In general, the kilovolts peak value for all extremity work, neck, and breast, should be within the limits of 25 to 40 kilovolts peak.

The milliampere-second value should be from 100 to 200 milliampere-seconds, the time value being sufficiently short to obviate the danger of motion, in most instances under 2 seconds, if possible.

The focal-film distance should be from 30 to 42 inches. The closer distance is preferable, if the apparatus available makes necessary an exposure time over 2 seconds.

The variable factor of choice is kilovolts peak. If the difference between steps on the autotransformer is 2 kilovolts peak or less, no other factor need be changed to control density.

Do not try to control density in the darkroom. Consistent results are possible only with proper processsing room conditions.

Figure 209 of the antero-posterior elbow demonstrates a difference of 1 kilovolt peak between exposures. In this example the technics employed were as follows: 200 milliampere-seconds, 40-inch distance. The kilovolts peak in exposure A is 30, in B it is 31, and in C it is 32. Note that even this small voltage change is visible. Comparing exposures A and C, the effect of a 2-kilovolts peak change may be noted.

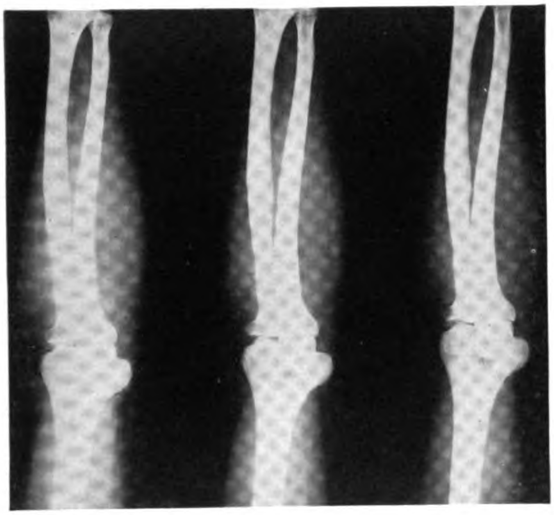


FIG. 209. Radiographs of antero-posterior elbow showing a difference of 1 kilovolt peak between exposures.

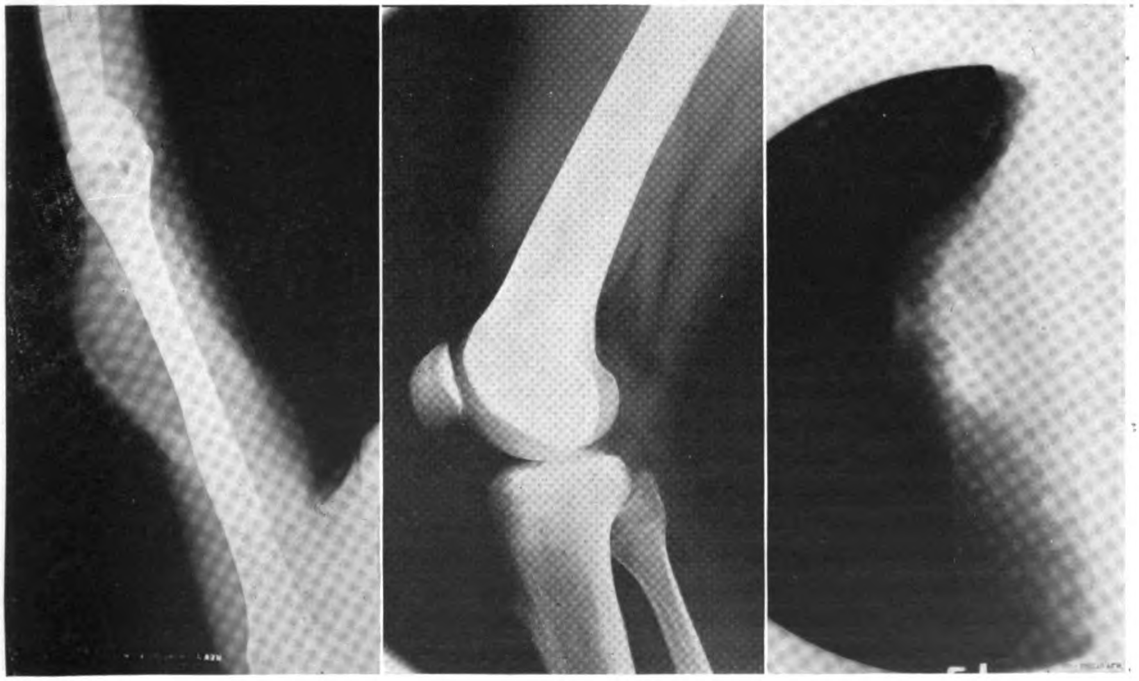
The latitude in soft tissue radiography is much less than for general work, but after a satisfactory procedure has been established by actual trial and error, little added difficulty should be experienced.

Through the courtesy of John R. Carty, M.D., Radiologist to New York Hospital, New York City, a number of examples of soft tissue radiography are given. Their use in this chapter is based strictly on technical considerations. The pathology shown, as given by Dr. Carty, is a better illustration of the value of soft tissue radiography.

The following chart should prove of value as a starting procedure only. The speed of screens, apparatus available, accuracy of machine calibration, etc., may make necessary a change of as much as 5 to 8 kilovolts peak from that given, or it may be necessary to use a different milliampere-second value. A few test exposures should enable the operator to establish a soft-tissue procedure that is just as much a matter of routine as any other type of work.

Part	*Milliampere-Seconds*	*Distance*	*Kilovolts Peak*
Hand and Wrist	200	40	25
Elbow and Ankle	200	40	30
Shoulder	200	40	36
Knee	200	40	32
Thigh	200	40	40
Breast	200	40	30

If a distance of 30 inches is necessary, reduce milliampere-seconds to 100, leaving other factors the same. Vary the kilovolts peak to change density.



Anatomy

THIS CHAPTER presents the necessary anatomical information which is generally required for x-ray technicians in order that they may accurately locate and properly position those regions requested by the radiologist.

The Extremities

Upper Extremity

The upper extremity is divided into four segments: the shoulder girdle, arm, forearm, and hand. The skeletal portion of this region may also be separated into segments corresponding to the above division. The bones of the *shoulder girdle* are the scapula and the clavicle; of the *arm,* the humerus; of the *forearm,* the ulna and radius; of the *hand,* the carpus, metacarpus, and the phalanges. Each segment will be considered separately.

Shoulder Girdle

Scapula

The scapula is a flat triangular bone situated on the upper posterior surface of the thorax over the first to the seventh ribs. It has two surfaces: anterior and posterior; three borders: vertebral, superior, and axillary; and three angles: superior, lateral, and inferior.

The anterior surface of the scapula is comparatively smooth and is slightly concave to conform to the contour of the thorax. Its posterior surface is slightly convex and is divided into two unequal areas by a projecting and roughened ridge of bone, the spine of the scapula. The spine has its beginning at the vertebral border and inclines upward across the surface of the bone, extending beyond the lateral angle to end in a flattened process, the acromion. The anterior surface of the acromion articulates with the distal end of the clavicle forming the apex of the shoulder. It is through this anterior juncture with the clavicle that the shoulder girdle has its sole bony attachment to the thorax. The posterior connection is accomplished through musculature only. The rhomboides and levator scapulae muscles constitute the vertebral elements of connection, while the serratus anterior muscle is the thoracic element.

The inferior angle of the scapula, formed by the convergence of the axillary and vertebral borders, is easily located on most patients, and is used as a landmark in radiography. The superior angle is formed by the superior and vertebral borders. The lateral angle, formed by the superior and axillary borders, ends in an abruptly thickened portion of bone, the glenoid cavity, which is separated from the main portion of the bone by a constricted region, the neck. This cavity which accommodates the head of the humerus is oval in shape and very shallow; being shallow, much freedom of movement of the humerus is possible. Extending forward and laterally from the neck of the scapula is the coracoid process; its prominence lies to the medial side of the head of the humerus.

Clavicle

The clavicle is an S-shaped bone that articulates laterally with the acromion process of the scapula and medially with the sternum through the sterno-clavicular articulation. The degree of curvature varies considerably among individuals and sexes.

Arm

Humerus

The humerus is the longest and largest bone of the upper extremity and is comprised of a shaft and two extremities. The head, or upper extremity, is a round, semispherical surface which articulates with the scapula; it is separated from the humeral shaft by a shallow groove, the anatomical neck. Lateral to the anatomical neck are two protruding areas of bone for muscle attachment, the greater and lesser tuberosities. Just below the tuberosities, the bone contracts to form the surgical neck, so called because it is frequently the site of pathological processes. The upper part of the shaft is round in cross-section but becomes triangular in its lower portion.

The lower extremity of the humerus is somewhat flattened and broad, forming on either side, medial and lateral epicondyles. Below the epicondyles are the articular surfaces for the bones of the forearm, the medial being called the trochlea, the lateral the capitulum.

Forearm

Ulna

The ulna is on the medial side of the forearm and articulates with the trochlea of the humerus. It is longer than the radius, and has at its upper extremity a thickened portion, the olecranon process. It is widest and strongest at its upper extremity, but tapers toward its lower extremity, where it terminates as the styloid process.

Radius

The radius is on the lateral side of the forearm and differs from the ulna in being smaller at its upper extremity and larger at its lower extremity. The upper extremity is cylindrical and has on its upper surface a shallow depression where it articulates with the capitulum of the humerus. The lower extremity of the radius is broad and flat, having on its lateral border a projection of bone, the styloid process. This is larger, though less pointed, than the similarly named process on the lower extremity of the ulna. The radius articulates with the proximal bones of the carpus.

Hand

The bones of the hand are twenty-seven in number which may be separated into divisions corresponding to the wrist, palm, and fingers.

Carpus

The carpus, or wrist, is composed of eight bones, arranged in two rows, a proximal and a distal. The proximal row articulates with the radius, the distal with the metacarpus.

Metacarpus

The metacarpus, or bones of the palm, is a series of five small long bones, each having a proximal portion, a body, and a distal portion. The proximal portion articulates with the carpus, the distal with the phalanges.

Phalanges

The phalanges are the bones of the fingers. Each finger is comprised of three phalanges: proximal, middle, and distal. The thumb has but a proximal and a distal phalanx.

Lower Extremity

Thigh

Femur

The femur, the largest bone in the skeleton, transmits the weight of the body from the pelvis to the tibia. It is divided into three parts: the superior extremity, composed of the head, neck, and trochanters; the shaft; and the inferior extremity made up of the condyles and epicondyles.

The head of the femur is attached to the shaft by the neck. The head is shaped like a half sphere and fits into the acetabulum, forming a ball-and-socket joint. At the junction of the neck and shaft of the femur are two prominent processes of bone, the upper one the greater trochanter, and the lower and smaller the lesser trochanter. Connecting the two trochanters on the anterior surface of the bone is a ridge, the trochanteric line; on the posterior surface, a crest, the trochanteric crest. The tips of the greater trochanters on each side, lying superficial in the upper, lateral thigh, become significant palpable landmarks as they mark the widest transverse line through the region of the hip joint.

The shaft is cylindrical in shape in the upper half but prismatic in shape in the lower half. The inferior extremity becomes wider and thicker, forming the medial and lateral condyles, which articulate with the upper extremity of the tibia; they are separated on the posterior surface by the intercondyloid fossa. Extending upward and anteriorly from the lateral condyle is the trochlea, a rounded prominence on which the patella glides; above the condyles on either side of the bone are the epicondyles.

Leg

Tibia

The tibia, the larger and more medial of the two bones of the leg, transmits the weight of the body to the foot. It has an upper extremity, a shaft, and a lower extremity. Its upper extremity has two concave areas that articulate with the condyles of the femur. The lower extremity has on its under surface the horizontal and medial articular surfaces of the ankle mortise for articulation with the tarsus. The bony support for this medial surface is the internal malleolus.

Fibula

The fibula is a long thin bone situated on the lateral side of the leg articulating with the tibia at its superior and inferior extremities. It is approximately the same length as the tibia. By extending below the inferior extremity of the tibia as the external malleolus, it forms the lateral articular surface of the ankle mortise.

Patella

The patella, also called the knee cap, is the largest of the sesamoid bones and is situated within the quadriceps femoris muscle tendon over the front of the femoral condyles. It is somewhat triangular in shape with the apex pointing downward. Its anterior surface is rough while the posterior or articular surface is smooth.

Foot

The bones of the foot are twenty-six in number, which may be separated into divisions called the tarsus, metatarsus, and phalanges.

Tarsus.—The tarsus, or ankle, is composed of seven bones. The calcaneus (or os calcis) is of special interest because it extends downward and backward from the talus and is the bone of the heel.

Metatarsus.—The metatarsus is a series of five small long bones, each having a proximal portion, a body, and a distal portion. The proximal portion articulates with the tarsus, the distal with the phalanges.

Phalanges.—The phalanges are the bones of the toes. Each toe is composed of three phalanges: proximal, middle, and distal. The great toe has but a proximal and a distal phalanx.

The Head

The bony framework of the skull is composed of twenty-two bones rigidly held together by very irregular joints known as sutures. It is chiefly a protective case for the brain and the organs of sight and hearing, and affords a framework for the entrances to the digestive and respiratory systems, respectively the oral and nasal cavities.

The skull is divided into two parts: the cerebral cranium and the visceral cranium. The former derives its name from the brain, which it surrounds, and will be referred to simply as the cranium. The bones of the cranium are composed of an inner plate and a thicker, smoother outer plate of compact bone, being separated by an intermediate layer of spongy tissue known as the diploë. The visceral cranium is so-called for the support and form it affords the oral, nasal, and orbital cavities; it will be referred to as the facial portion, or the bones of the face.

The bones of the cranium are: the frontal, two parietals, the occipital, two temporals, the sphenoid, and the ethmoid, making eight in number. The facial portion of the skull is composed of fifteen bones: the mandible in two united halves, two maxillary, two zygomatic, two nasal, two inferior turbinate, two lachrymal, a single vomer and two palatine bones.

Bones of the Cranium

Frontal Bone

The frontal bone forms the anterior wall of the cranium. It is divided into two parts: the squamous portion, having the external form of the forehead; and the orbital portion, which forms the roof of each orbital cavity.

On either side of the squamous portion, commonly called the forehead, is the frontal eminence. On the superior margin of either orbit is a prominent ridge of bone, the superciliary ridge, and between these ridges at the midline is a depressed area, the glabella. At the lateral and upper margins of the squamous portion, a very irregular coronal suture unites the frontal bone with the parietal bones and the greater wings of the sphenoid bone.

The glabella and the two superciliary ridges, in part, mark the position of right and left frontal sinuses. These air cavities, occupying a space between the two plates of the frontal bone, are separated by a thin bony septum and extend a variable distance lateralward and upward from the midline into the squamous portion.

Parietal Bones

The parietal bones form the top and sides of the cranium. They are quadrilateral in shape and are joined at the midline, at the top of the cranium, by the sagittal suture. The anterior border of each bone joins with the frontal bone at the coronal suture; the posterior border of each with the occipital bone at the lambdoid suture; and the inferior border with the temporal bones on each side at the squamous suture.

Occipital Bone

The occipital bone forms part of the posterior and part of the base of the skull and is the only bone of the skull that articulates with the spine. It is divided into four parts termed: squamous, right and left lateral, and basilar. These correspond to the four separate parts of which the bone consists during infancy; by the seventh year the parts unite to form one continuous bone.

The squamous portion is the largest part of the bone and is situated above and behind the foramen magnum. On the external surface, midway between the foramen magnum and the lambdoid suture, is a bony projection, the external occipital protuberance. On either side of the foramen are the lateral portions, having on their external surfaces the occipital condyles which articulate with the atlas. The anterior rim of the foramen magnum is made complete by the fusion of both lateral portions with the basilar portion. Between the eighteenth and the twenty-fifth year, the basilar part of the occipital bone unites with the sphenoid bone.

Temporal Bone

The temporal bone is located at the sides and base of the cranium contributing also to the bones of the face. It consists of three parts: the squamous, the mastoid, and the petrous portions and contains the middle and inner ear, the mastoid cells, and the articular surfaces for the lower jaw. Projecting downward and forward from the inferior surface of the temporal bone is a small, slender shaft of bony tissue, the styloid process; projecting forward from the lower border of the squamous portion is the zygomatic process.

The squamous portion completes the sidewall of the cranium by articulating with the sphenoid and parietal bones.

The mastoid portion forms the prominence of bone behind the ear known as the mastoid process; it is absent in the newborn but well developed by the fifth year.

The petrous portion is a pyramidal projection of dense bony tissue on the medial side of the temporal bone, extending medialward and forward to the angle formed by the posterior border of the greater wing of the sphenoid and the basilar part of the occipital bones. Its two superior surfaces form part of the cranial floor; they join along the whole extent of the bone to form a markedly elevated ridge, the petrous ridge.

Sphenoid Bone

This complicated bone enters into the formation of the base of the cranium and deeper portions of the facial group; it is located slightly in front of the midpoint along the base of the skull.

A short distance anterior to the foramen magnum, the basilar portion of the sphenoid bone is rigidly fused to the occipital bone. Extending forward in the midline from this point, the body of the sphenoid bone forms a portion of the base of the cranium. In its very center is a marked depression on its surface, the sella turcica; open on each side, the sella is guarded in front and behind by four prongs of bone known as the anterior and posterior clinoid processes. The anterior processes, one on each side, also help to form the foramina through which the optic nerves pass from orbital to cranial cavity; small wing-like lateral extensions from the roots of the anterior clinoid processes are termed the lesser wings of the sphenoid bone. They are sharp ridges and stand above elongated openings, the superior orbital fissures, which also connect the orbital cavity with the cranial cavity.

Much of the body of the sphenoid bone directly below the sella turcica is replaced by two large air cells, the sphenoid sinuses, these being separated by a thin bony septum; they communicate with the most superior and posterior extent of the nasal cavities.

Lateral extensions from the body of the bone, the greater wings of the sphenoid bone, form a large part of the mid-portion of the floor of the cranial cavity. On each side the greater wings extend to the lower lateral walls of the cranium; in so doing, they meet and articulate with the temporal, parietal, frontal, and zygomatic bones.

In addition to forming the deeper portions of the orbital cavities, inferior extensions of the bone, as the pterygoid plates, help to support the deeper parts of the nasal and oral cavities.

Ethmoid Bone

The ethmoid bone is cuboid in shape and situated at the anterior part of the base of the cranium. On either side of the perpendicular plate which contributes to the nasal septum are two areas of air cells, the ethmoidal sinuses. The bony structure of the walls limiting these cells is very thin or incomplete. While there is considerable variation in the position and number (eight to twenty) of individual air cells, those in the anterior part of the cuboid are grouped as the anterior ethmoidal cells, while those in the posterior portion are the posterior ethmoidal cells. The lateral walls of the ethmoid bone form part of the medial walls of the orbital cavities, while the space to either side of the perpendicular plate, between it and the lateral masses, constitute the upper reaches of the nasal cavity.

A thickened triangular extension of the perpendicular plate protrudes into the anterior floor of the cranial cavity as the crista galli.

Bones of the Face

Maxilla

The two maxillary bones unite in adult life to form the entire upper jaw. They form the floor of the orbital cavities, the floor and lateral walls of the nasal cavities and the roof of the mouth. Each body of the maxilla contains a large triangular cavity, the maxillary sinus or antrum. On the inferior order, to each side, is the alveolar process which accommodates the upper teeth. The zygomatic process is situated at the anterior and lateral border of each maxilla and projects posteriorly to unite with the maxillary process of the zygomatic bone, forming the prominence of the cheek.

Mandible

The mandible, or inferior maxilla, is the largest and strongest of the bones of the face, and is the only movable bone of the head. It consists of a horseshoe-shaped portion, the body, and two rami which arise from the posterior portions of the body. Along the upper border of the body is the alveolar process for the accommodation of the lower teeth. At the midline on the mandible is a ridge of bone, the symphysis, marking the union of the two lateral portions of the body. The point, posteriorly, where the body of the mandible turns sharply upwards to become the ramus, is designated as the angle of the mandible.

On the upper extremity of each ramus are two processes separated by the mandibular notch. Anteriorly is the coronoid process to which the temporal muscle is attached; the posterior projection is called the condyloid process, and it articulates with the temporal bone. This joint is referred to as the temporo-mandibular articulation.

Spinal Column

The spinal column is located at the midline in the posterior region of the body and consists of a series of bones, the vertebrae, which articulate with one another to form a flexible column; it supports the body trunk and protects the spinal cord. There are thirty-three vertebrae: seven in the cervical region, twelve in the thoracic region, five in the lumbar region, five in the sacrum, and four in the coccygeal region. At an early period of life the five segments of the sacrum are separate, but later between the eighteenth and twenty-fifth year they fuse; frequently the first piece of the coccyx fuses with the sacrum.

Each of the five regions of the spine has its own characteristic antero-posterior curvature, those of the cervical and lumbar regions being convex anteriorly, those of the thoracic and sacro-coccygeal regions being concave anteriorly. All vertebrae have certain characteristics in common. A typical vertebra is composed of two main parts: the body and the neural arch. The body is somewhat cylindrical in shape and forms the largest part of the vertebra; it supports the body weight. Between the bodies are interposed intervertebral discs of elastic fibrocartilage which serve to absorb forces or shocks. The neural arch is made up of two pedicles, two laminae, two transverse processes, one spinous process and four articular processes.

The first cervical vertebra, or atlas, which articulates with the skull, has no true body; the spinous process is extremely small, while the transverse processes are thicker and stronger than those of the other cervical vertebrae. The second cervical vertebra, or axis, is characterized by a prominent projection of bone upward from the body known as the odontoid process which articulates with the atlas. This vertebra is characterized by a very large spinous process.

Near the junction of pedicle and vertebral body on the twelve thoracic segments are placed articular surfaces to receive the heads of the ribs. The thoracic spinous processes are long and inclined downward.

The lumbar vertebrae represent typical vertebrae; their spinous processes are large and horizontal; their transverse processes extend lateralward from the junction of lamina and pedicle. This section of the vertebral column affords a freedom of movement aided by large facets at each intervertebral articulation and by absence of any accessory bony attachments.

The sacrum is a wedge-shaped bone that represents the fusion of five sacral segments into one rigid piece. Broad above, it acts as a base upon which the spinal column rests; to each side it articulates with innominate bones at broad irregular sacro-iliac joints. By its concavity and its marked posterior position, the sacrum forms the roof and posterior boundary of the true pelvis.

The coccygeal segments are usually four in number, projecting downward and forward in a curve from the lower end of the sacrum. The individual segments are sometimes fused together forming one bone, and it is not uncommon for this bone to become fused to the sacrum, especially in older people.

Pelvis

The pelvis may be defined as a basin-shaped ring of bone at the inferior extremity of the trunk supporting the spinal column and resting upon the lower extremities. It is composed of the sacrum and coccyx behind, and the two innominate, or hip bones at the sides and in front.

Innominate Bone

This bone, together with its fellow of the opposite side, forms the lateral and anterior walls of the pelvis. Each hip bone articulates with the sacrum at the sacro-iliac joint, and with each other at the pubic symphysis. Early in life the bone is composed of three parts: the ilium, the ischium, and the pubis, but after puberty they unite to form one bone. The junction of the three bones is at the acetabulum, a cup-shaped cavity in which the head of the femur articulates.

Ilium

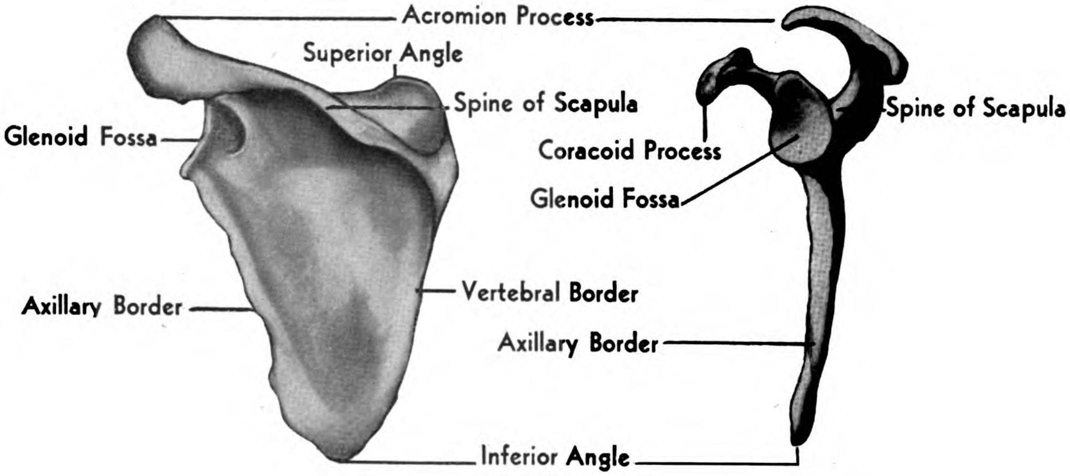
The ilium, the largest bone of the hip, is composed of two parts: the ala, and the body. The ala is a broad expanded portion of the bone which serves as a support and protection for the abdominal viscera. Its upper border, the crest of the ilium, is a thick and rough ridge of bone ending anteriorly in a prominent bony projection, the anterior superior spine. The body enters into the formation of the acetabulum comprising approximately two-fifths of it.

Ischium

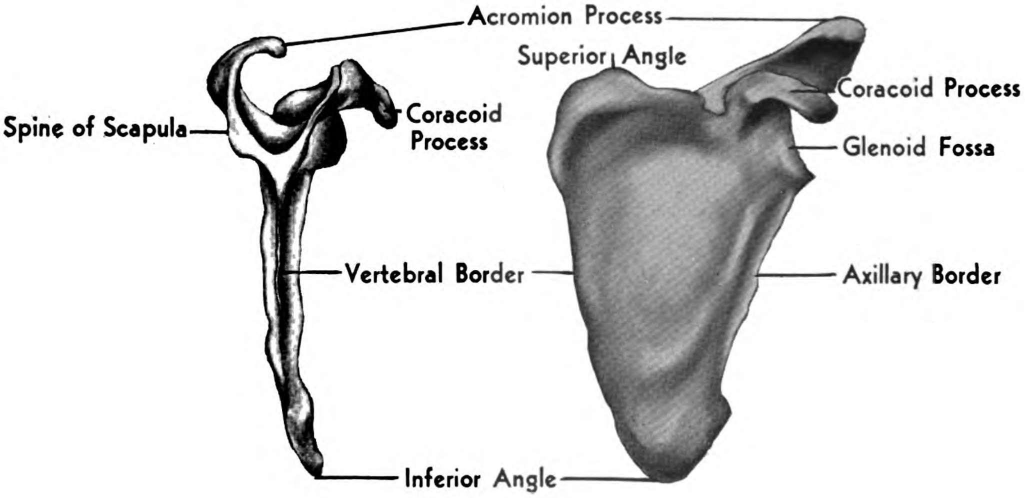
The ischium is the thickest and strongest of the three bones. It extends inferiorly and medially from the acetabulum of which it forms approximately two-fifths. The descending portion is thick and rough. The inferior surface is known as the tuberosity. The anterior portion extends forward to join the pubis. Extending backward and medialward from the upper and posterior border of the ischium is a prominent projection of bone, the spine of the ischium.

Pubis

The pubis extends forward and medialward from the acetabulum to articulate with its fellow of the opposite side, forming the pubic symphysis. From this point a bar of bone, the inferior pubic ramus, extends downward to meet and fuse with a similar extension of bone from the ischium.

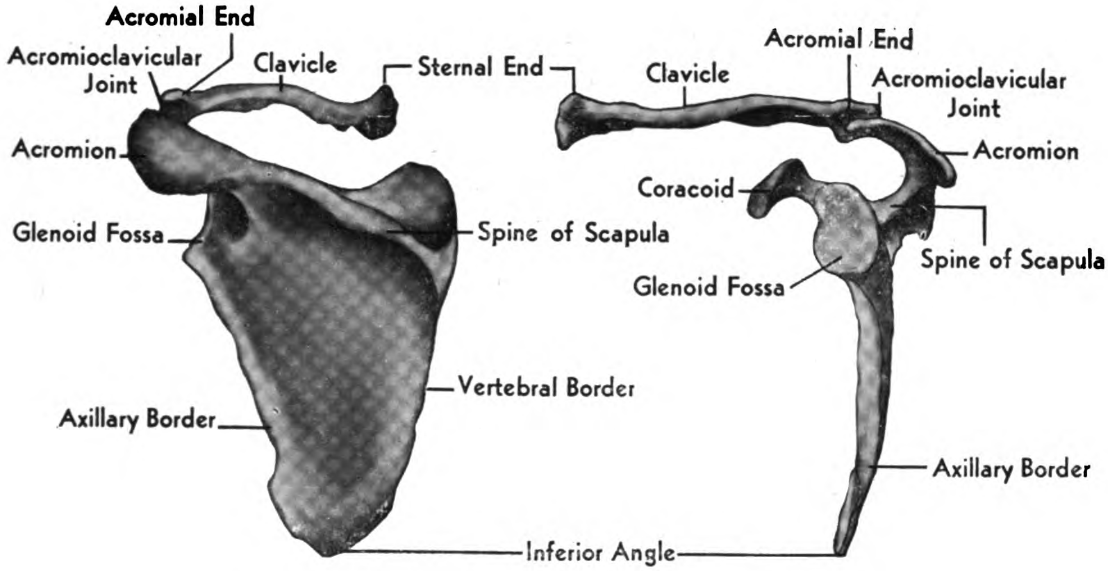


Posterior Surface *Axillary View*



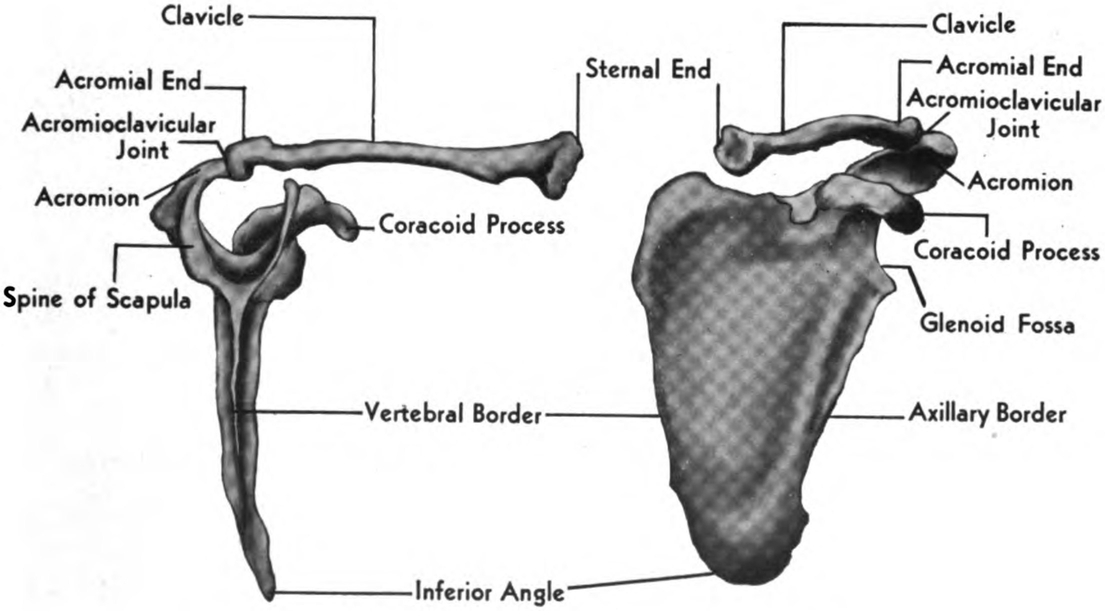
Vertebral View *Anterior Surface*

Fig. 210. The Left Scapula.



Posterior View

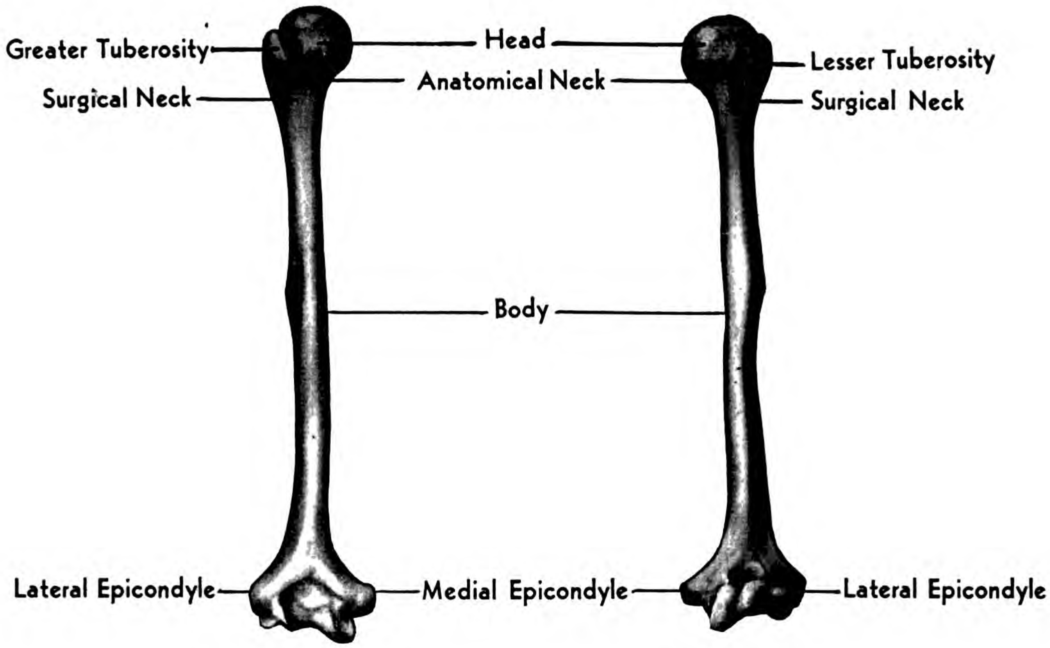
Axillary View



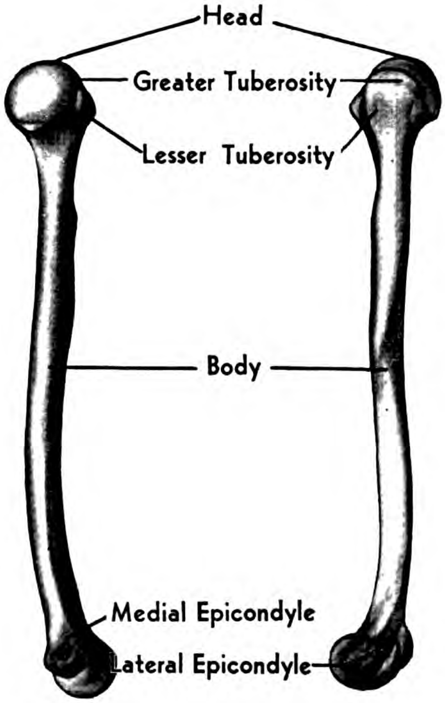
Vertebral View

Anterior View

Fig. 211. The Shoulder Girdle.



Posterior View *Anterior View*



Medial View *Lateral View*

Fig. 212. The Left Humerus.

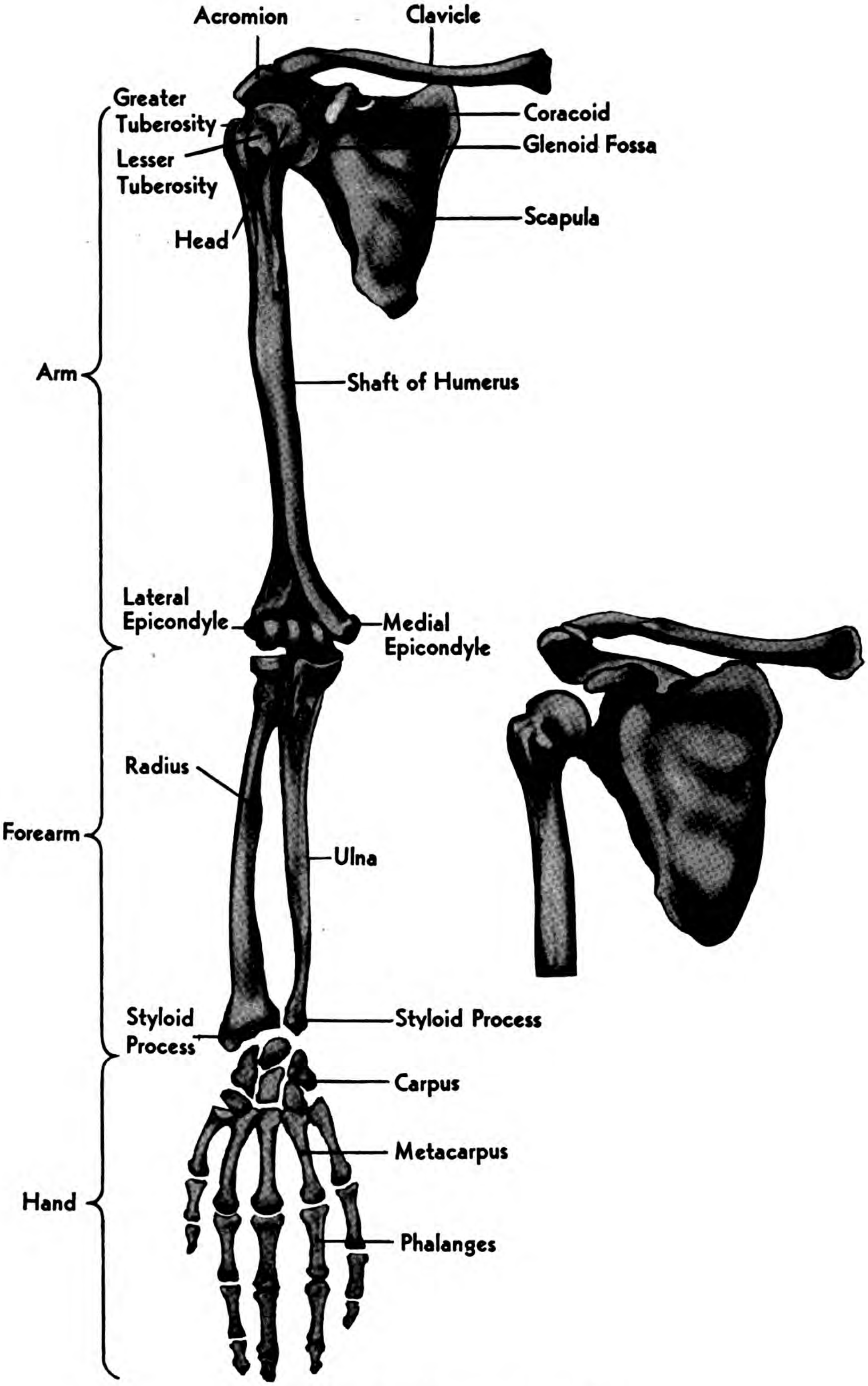


Fig. 213. The Upper Extremity.

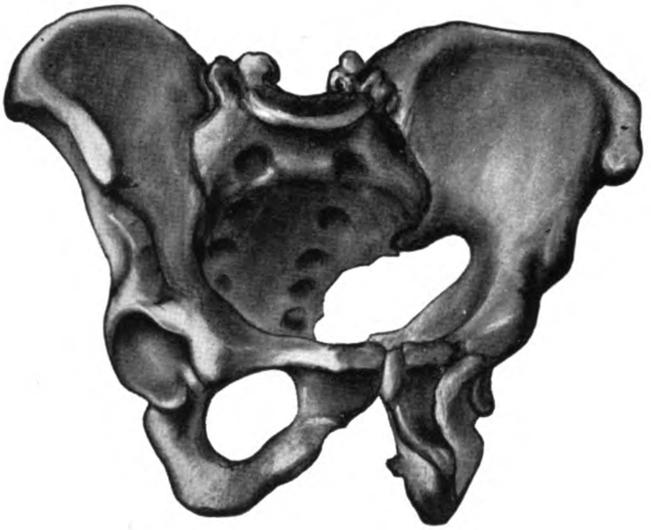


Fig. 214. Pelvis—Oblique View.

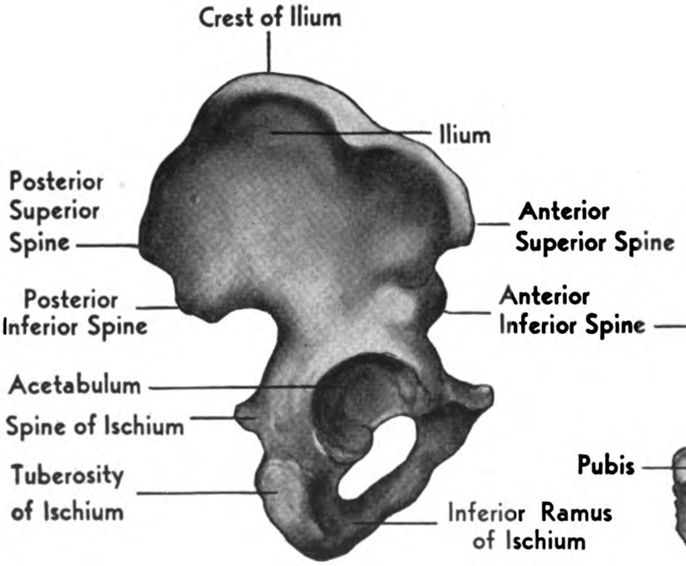


Fig. 215. Hip Bone—Lateral View.

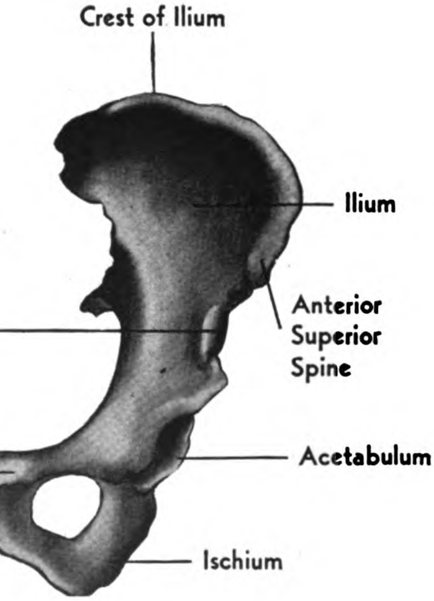


Fig. 216. Left Hip Bone—Anterior View.

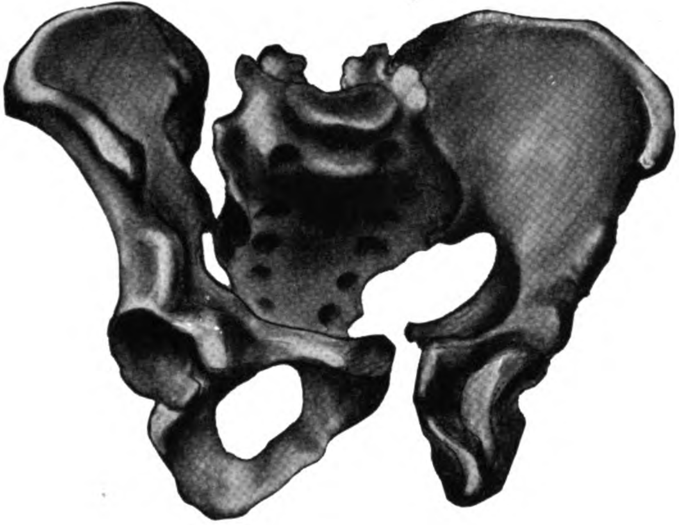


Fig. 217. The Pelvis—Oblique View (Showing Separation of Ilium and Sacrum).

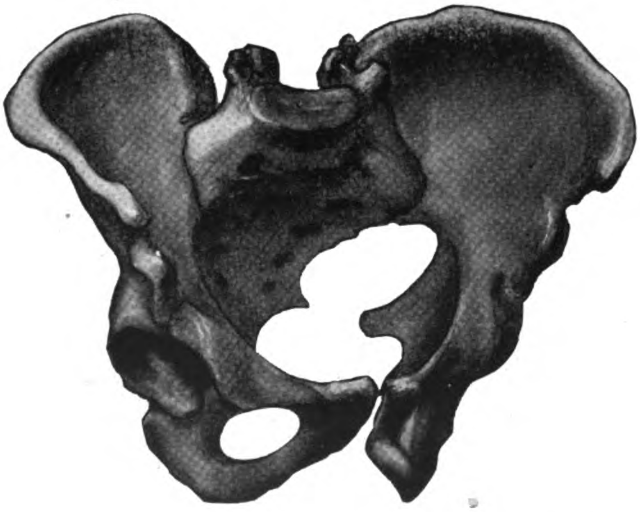


Fig. 218. The Pelvis—Oblique View (Forward Tilt to Show Spine of Ischium).

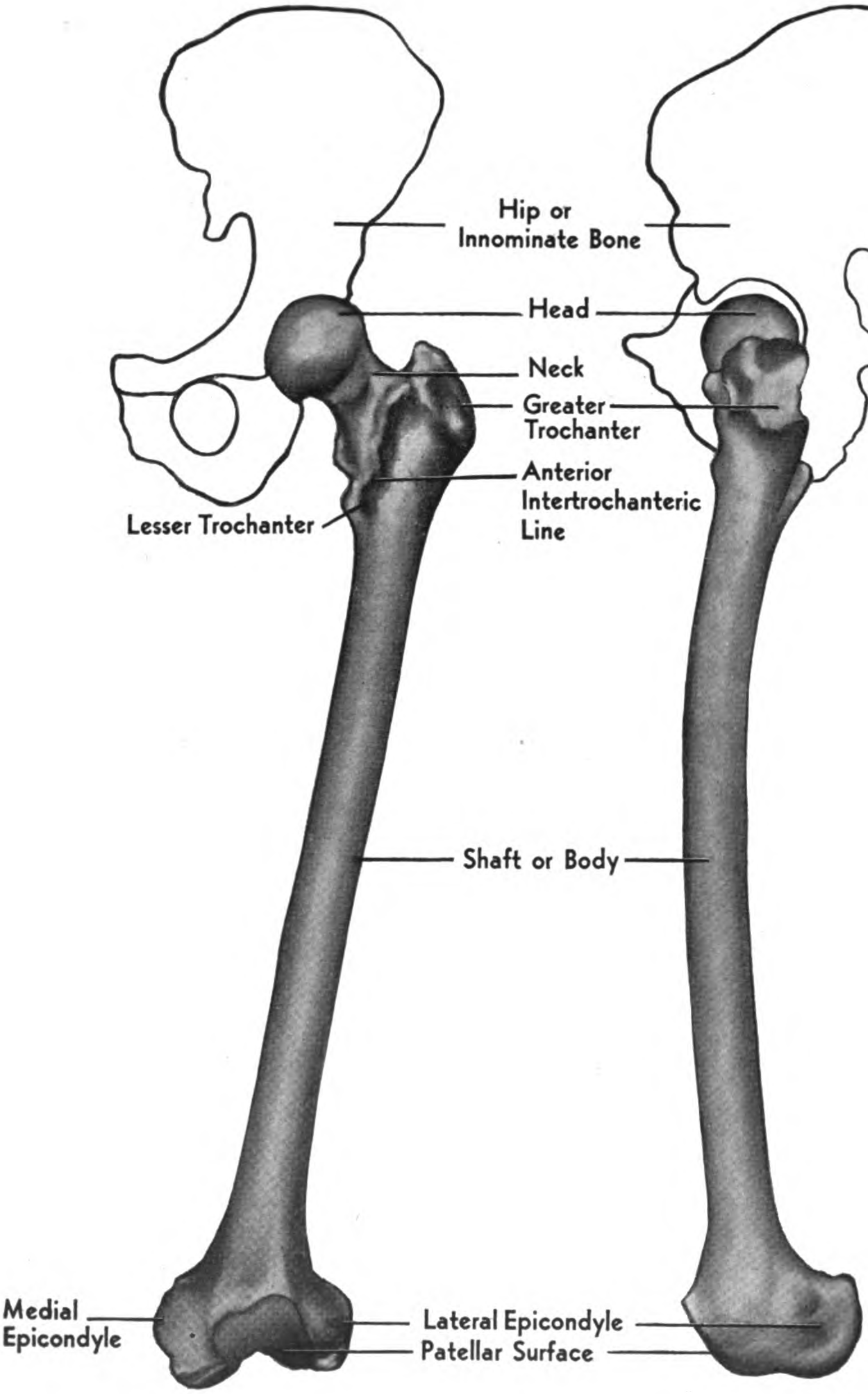


Fig. 219. The Left Femur.

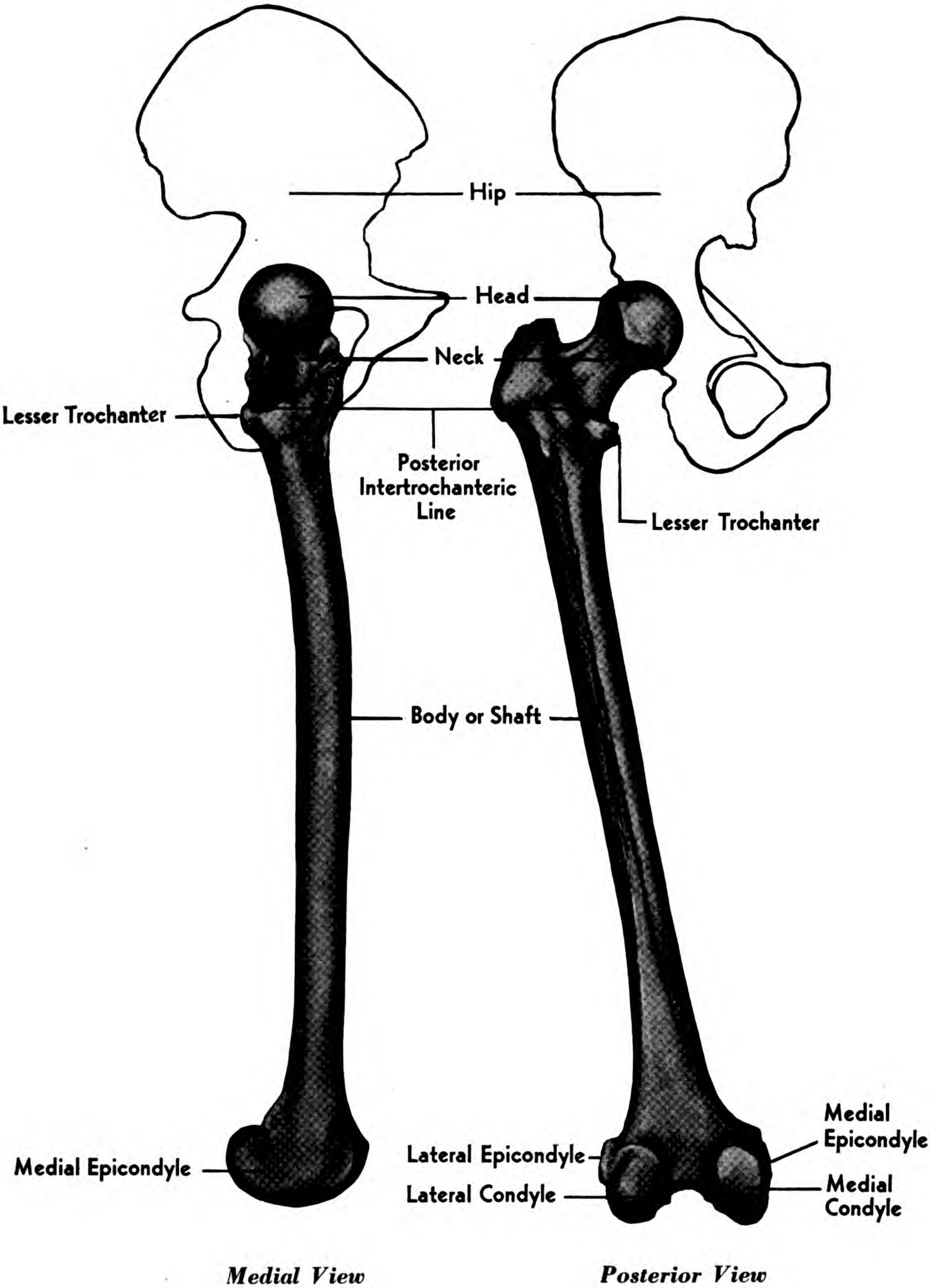


Fig. 220. The Left Femur.

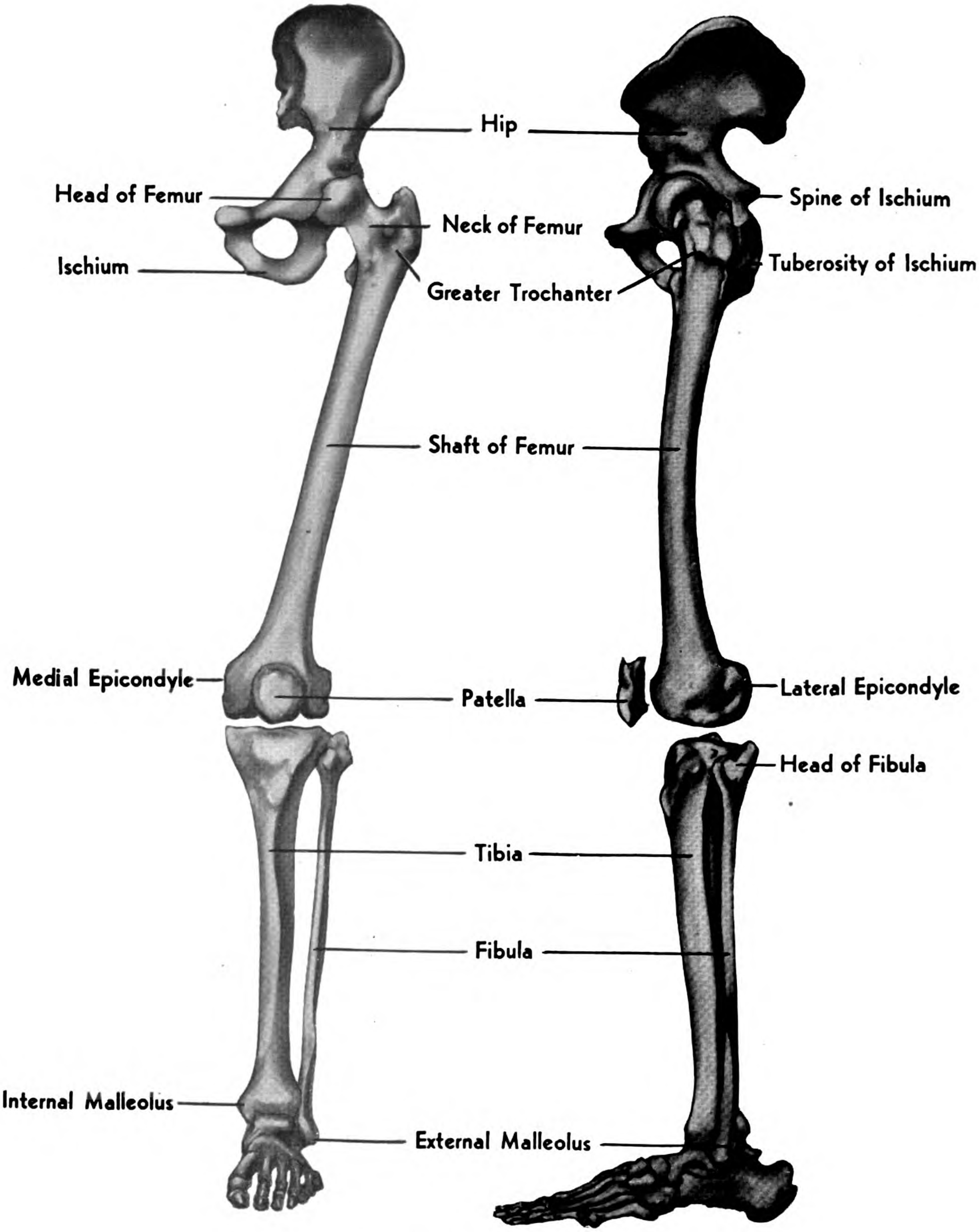


Fig. 221. The Lower Extremity.

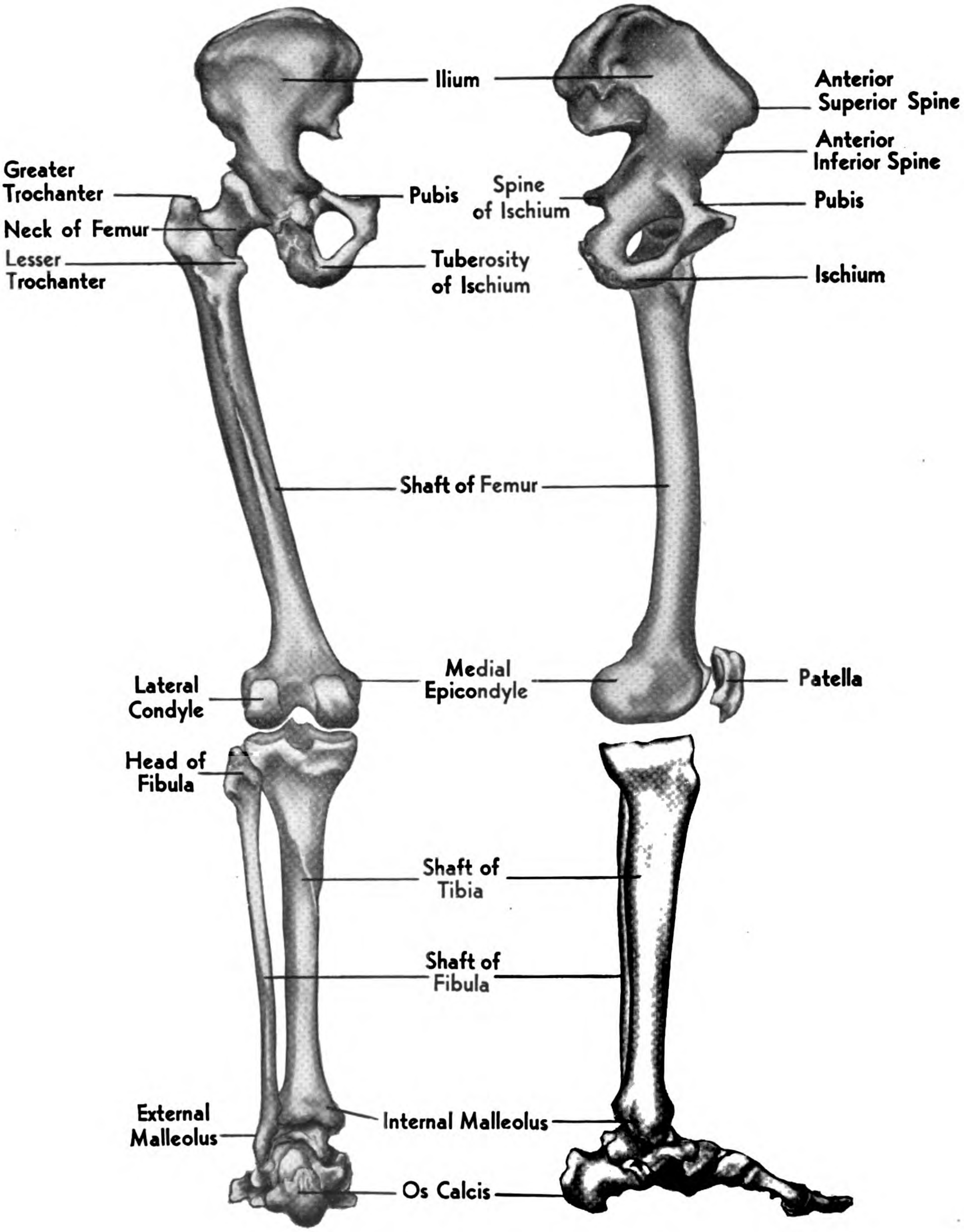


Fig. 222. The Lower Extremity.

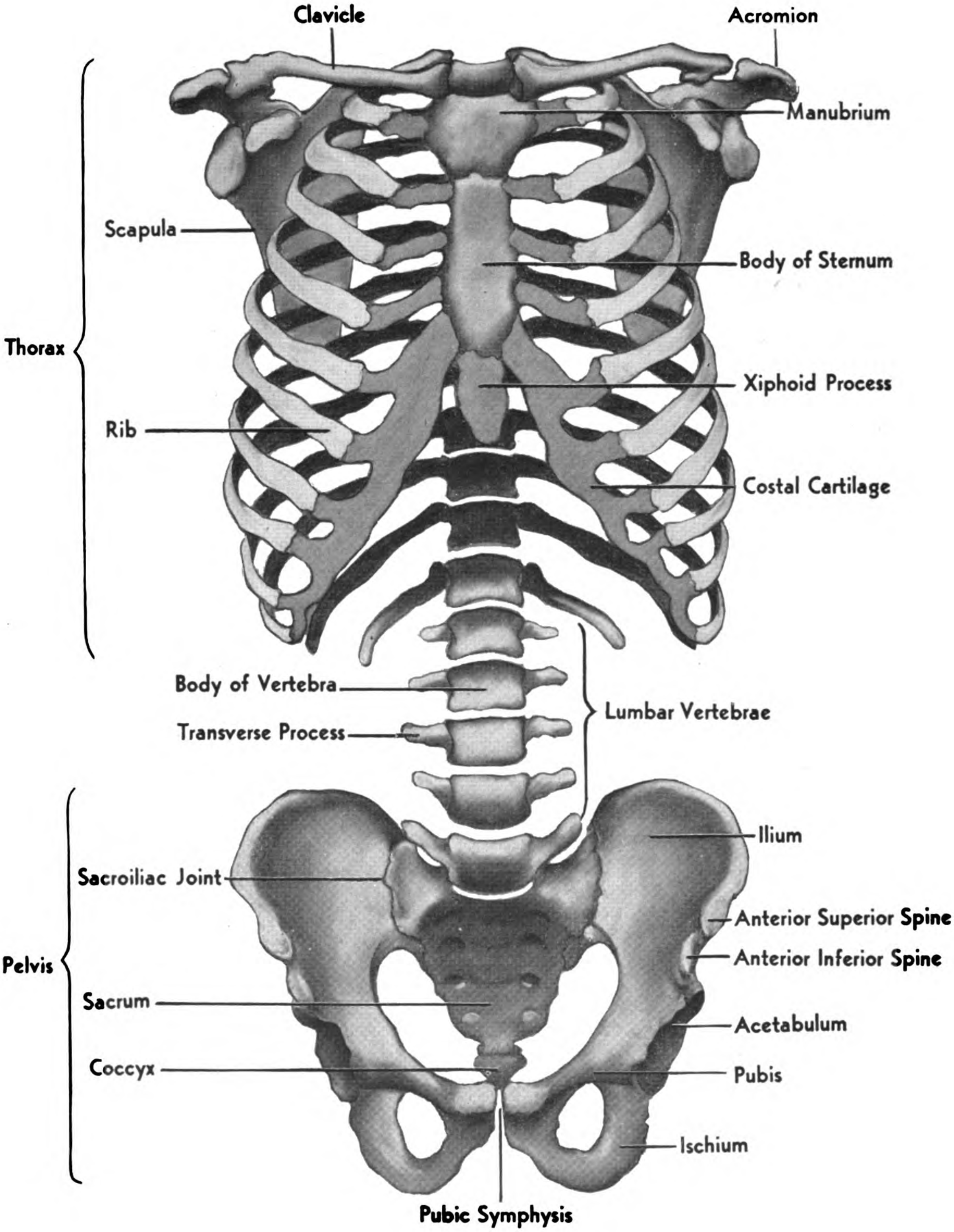


Fig. 223. The Bony Framework of Trunk and Pelvis—Anterior View.

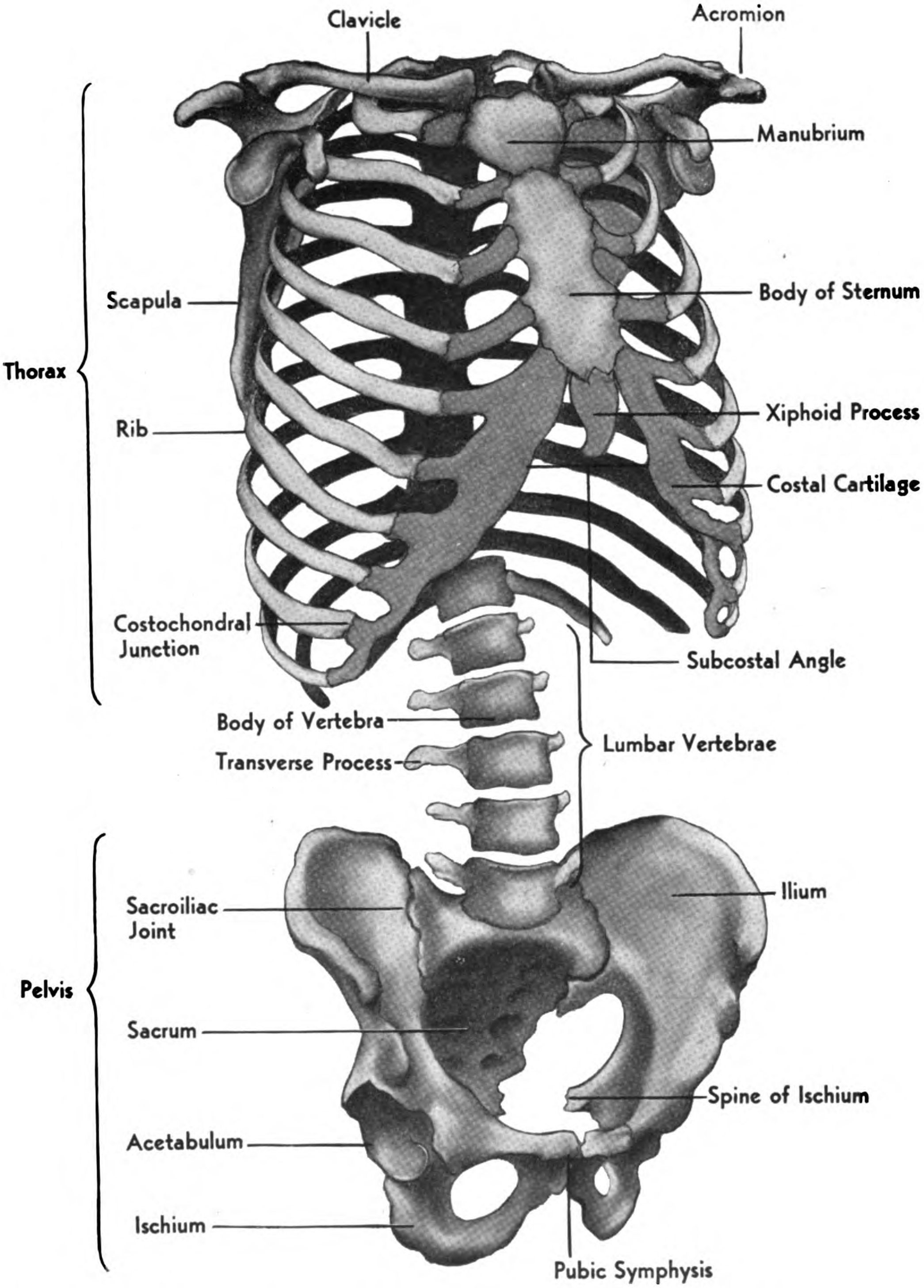


Fig. 224. The Bony Framework of Trunk and Pelvis—Anterior Oblique View.

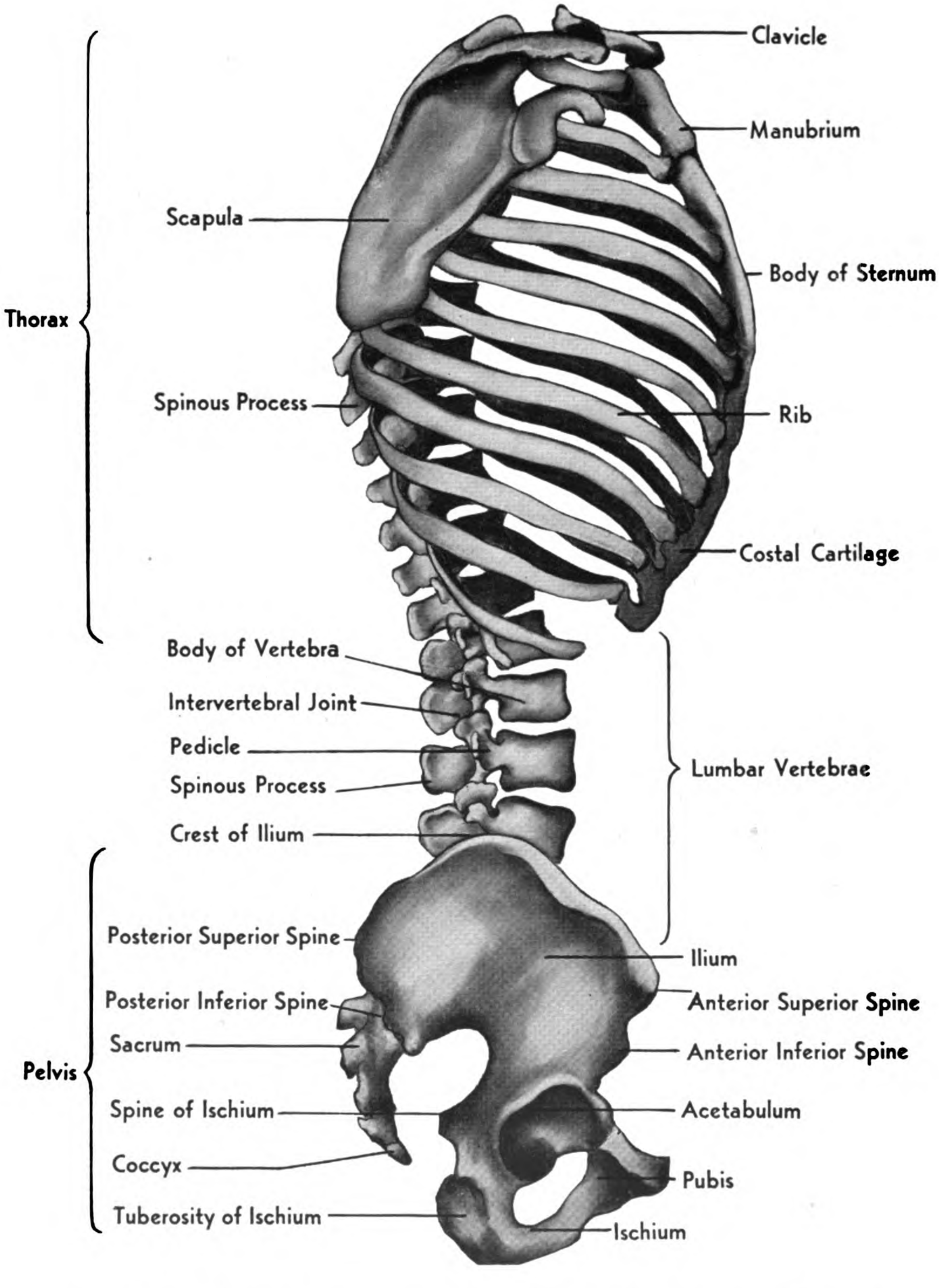


Fig. 225. The Bony Framework of Trunk and Pelvis—Lateral View.

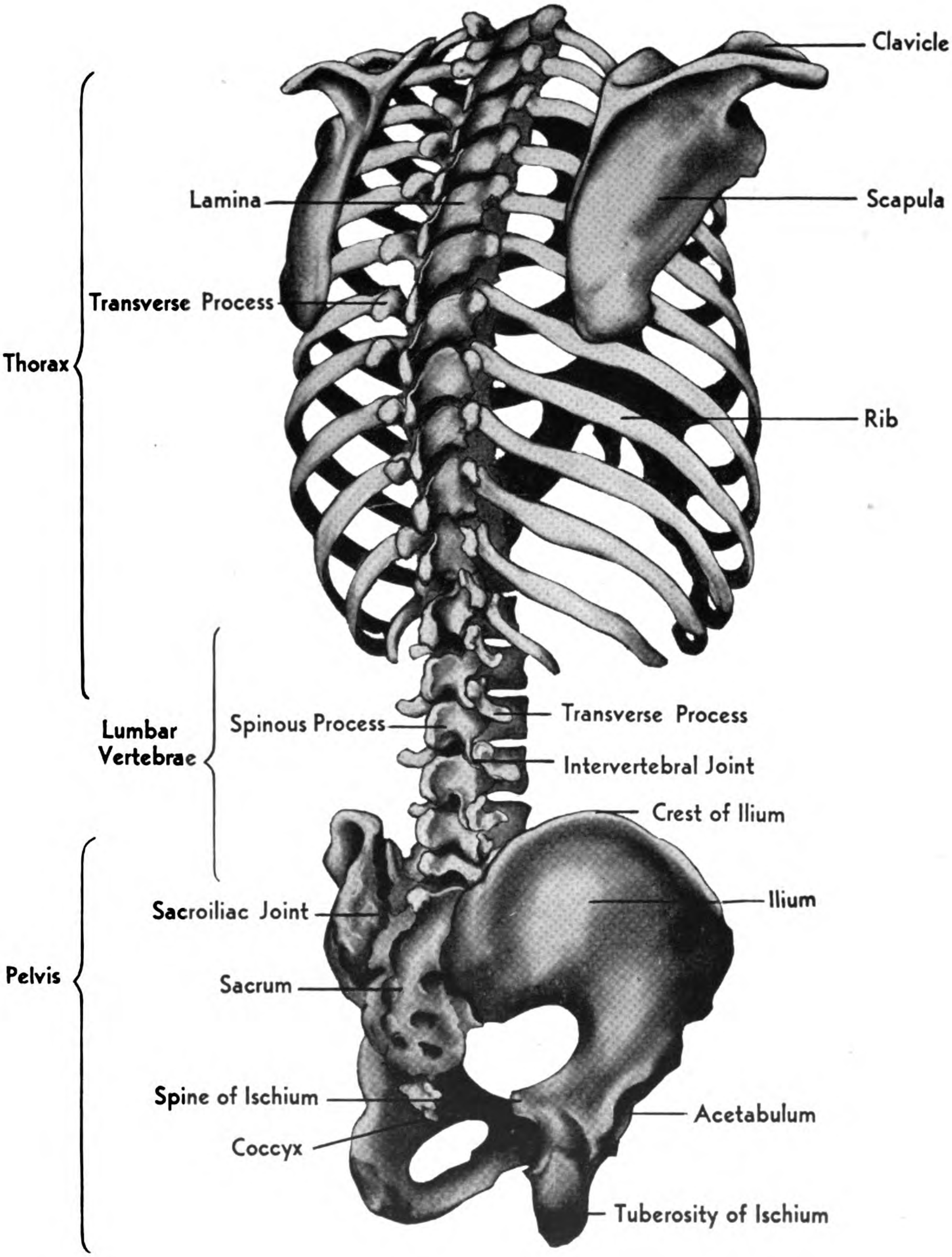


Fig. 226. The Bony Framework of Trunk and Pelvis—Posterior Oblique View.

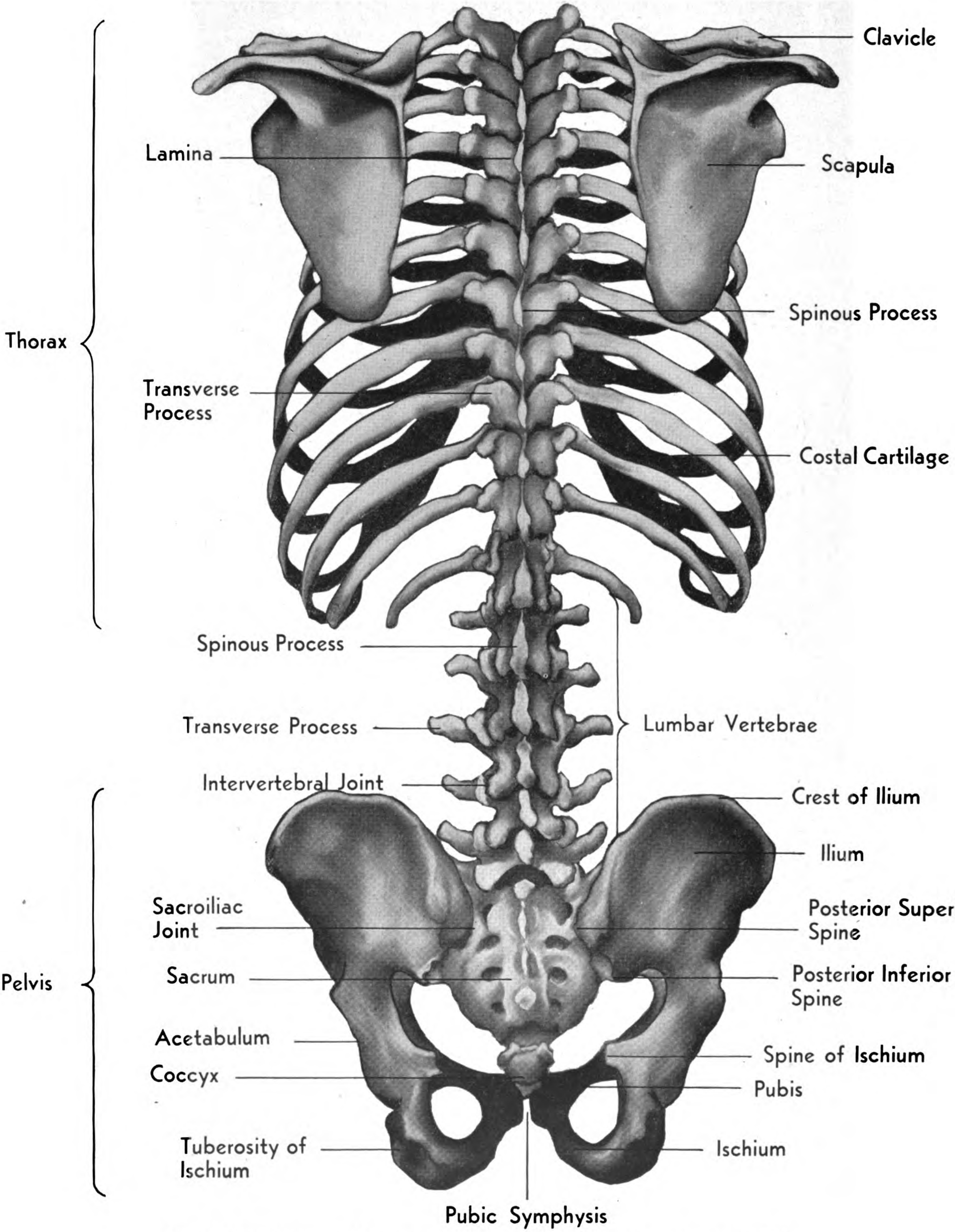


Fig. 227. The Bony Framework of Trunk and Pelvis—Posterior View.

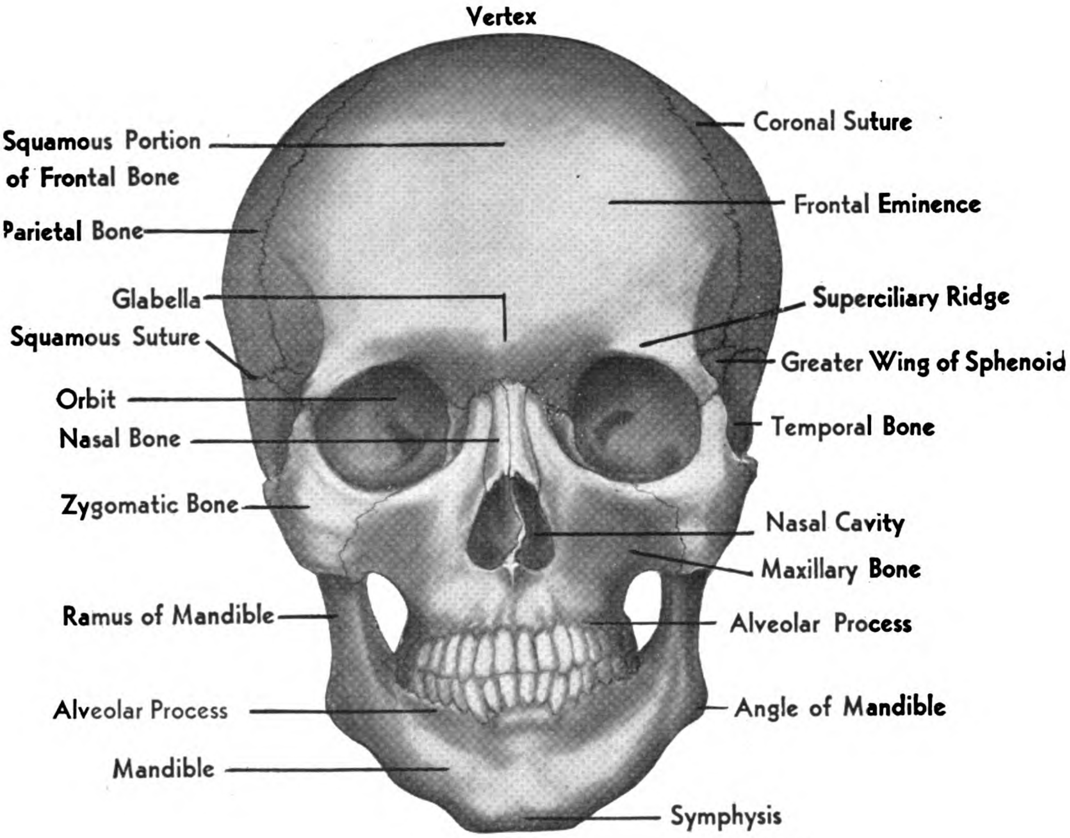


Fig. 228. The Skull—Anterior View.

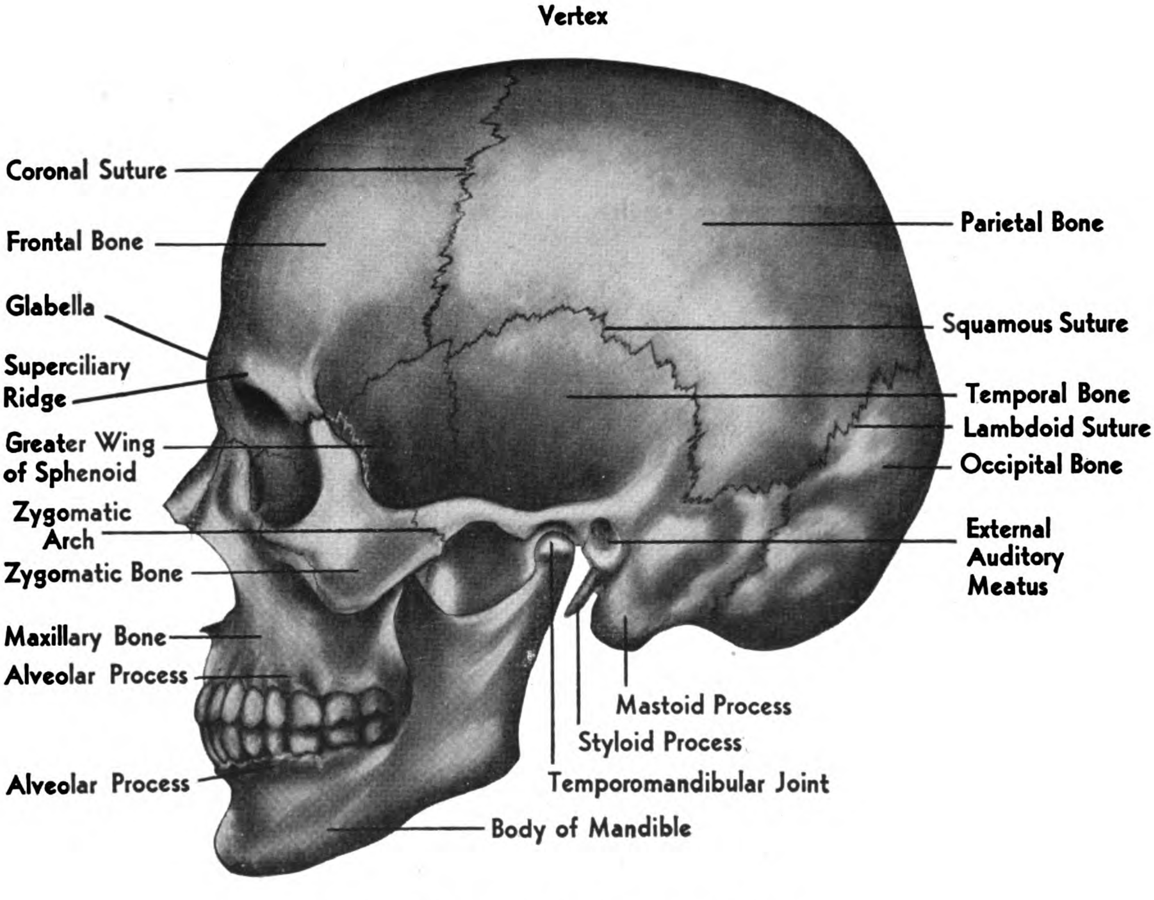
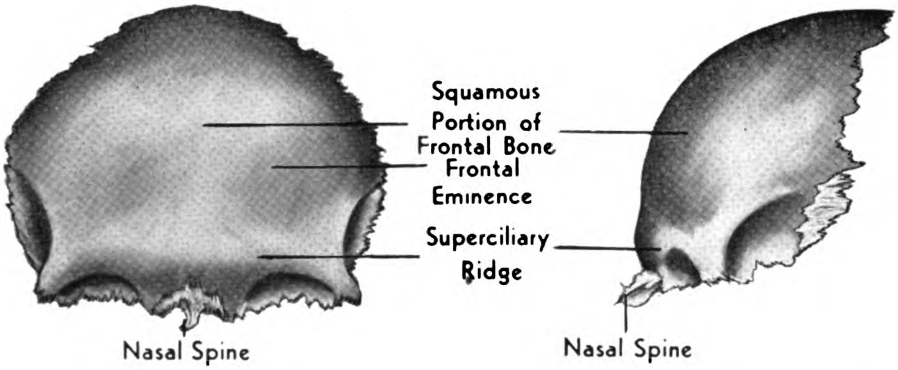
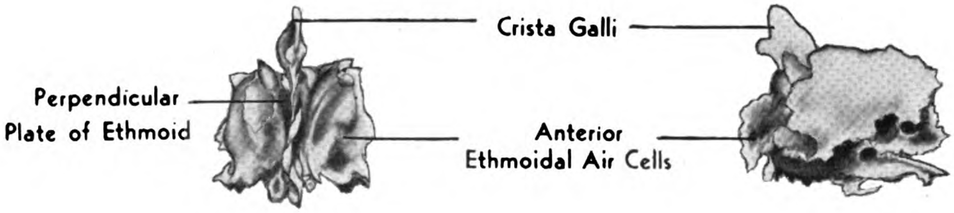


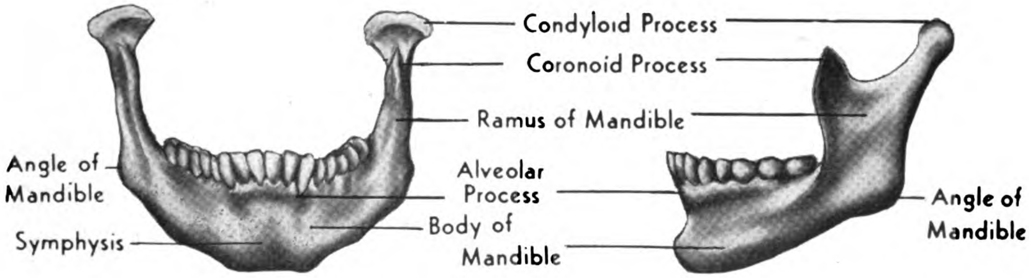
Fig. 229. The Skull—Lateral View.



Anterior View *Lateral View*

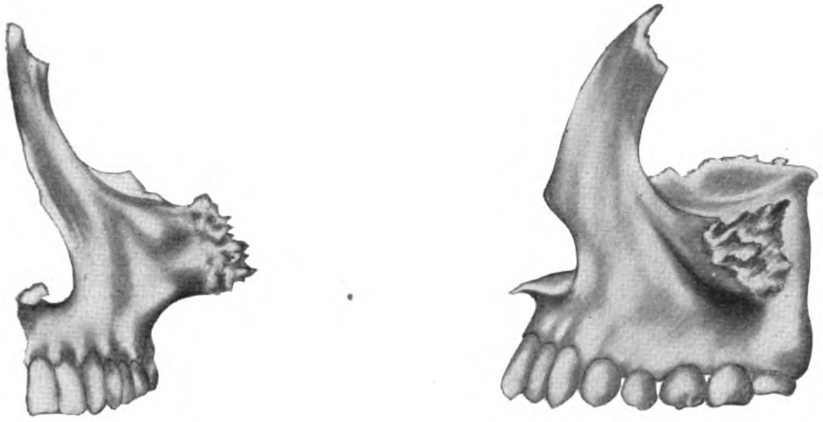


Anterior View *Lateral View*

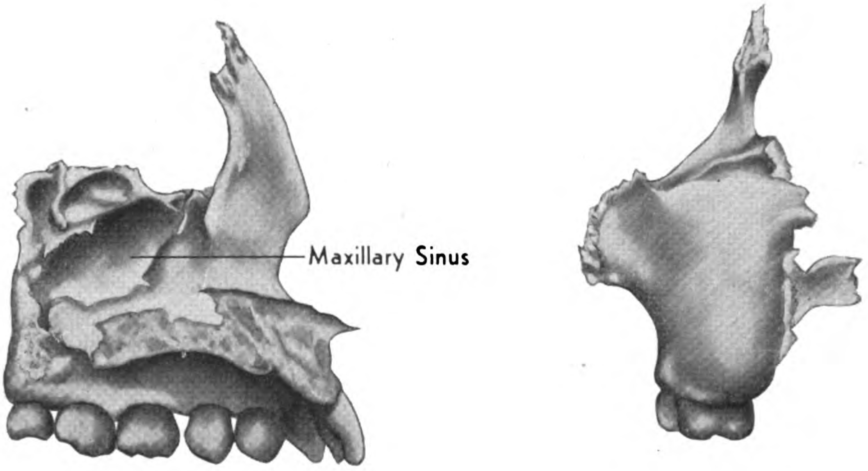


Anterior View *Lateral View*

Fig. 230. The Frontal, Ethmoid and Mandible.



Anterior View *Lateral View*



Internal View *Posterior View*

Fig. 231. The Left Maxillary Bone.

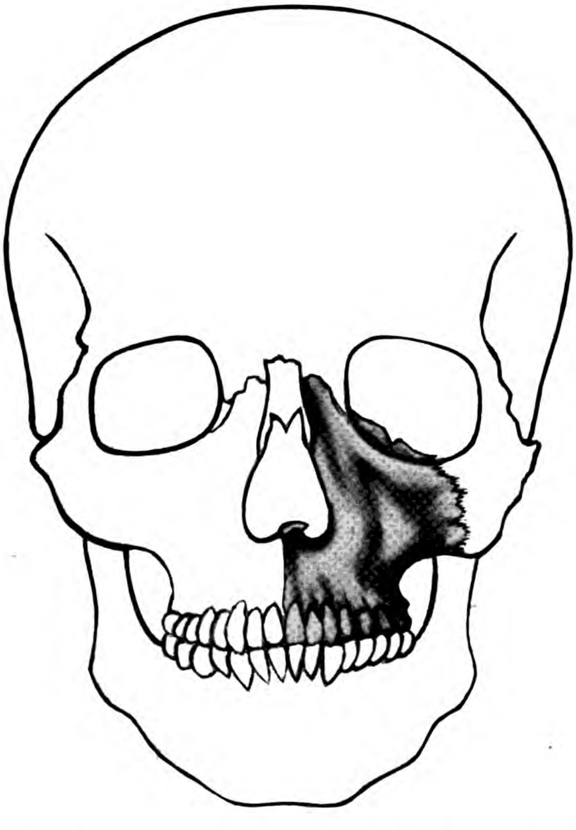
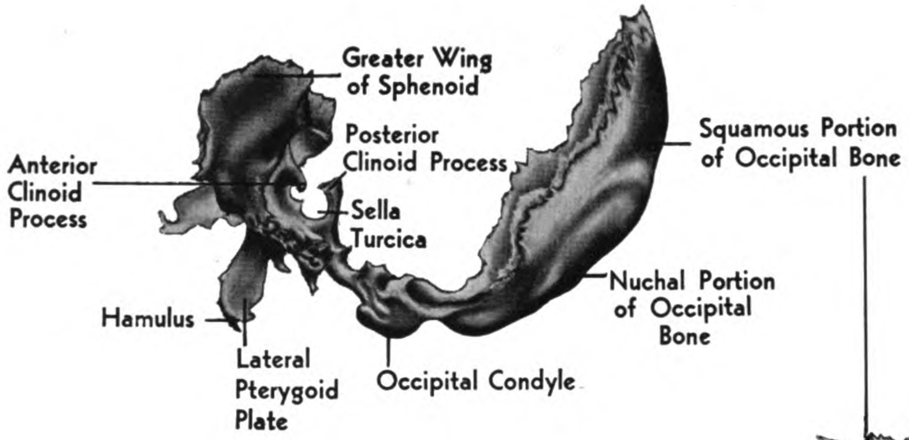
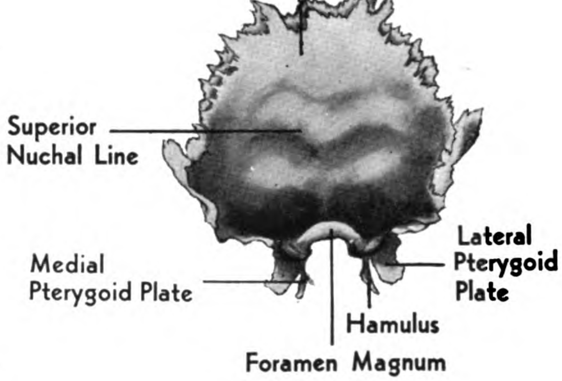


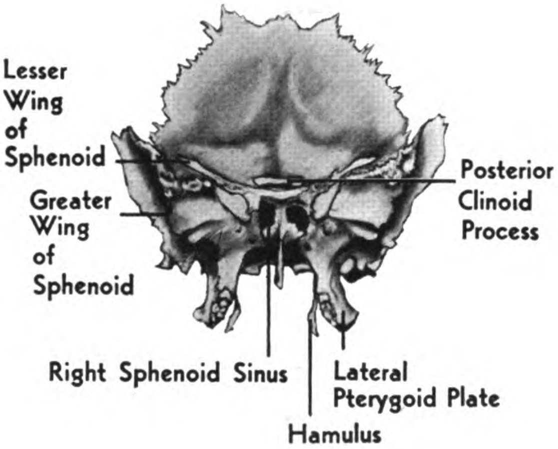
Fig. 232. The Left Maxillary Bone in Its Relation to the Skull.



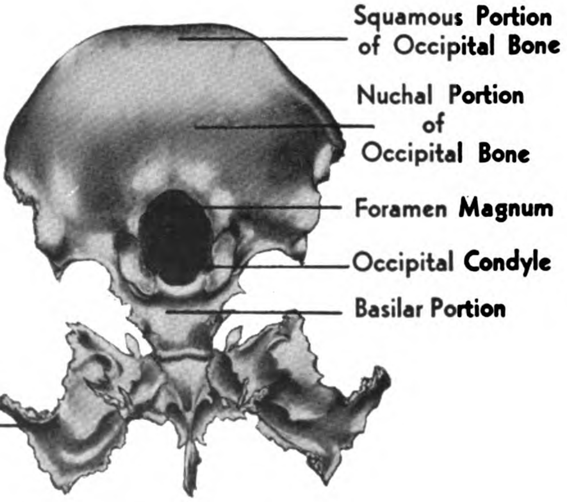
Lateral View



Posterior View



Anterior View



Basilar View

Fig. 233. The Sphenoid and Occipital Bone.

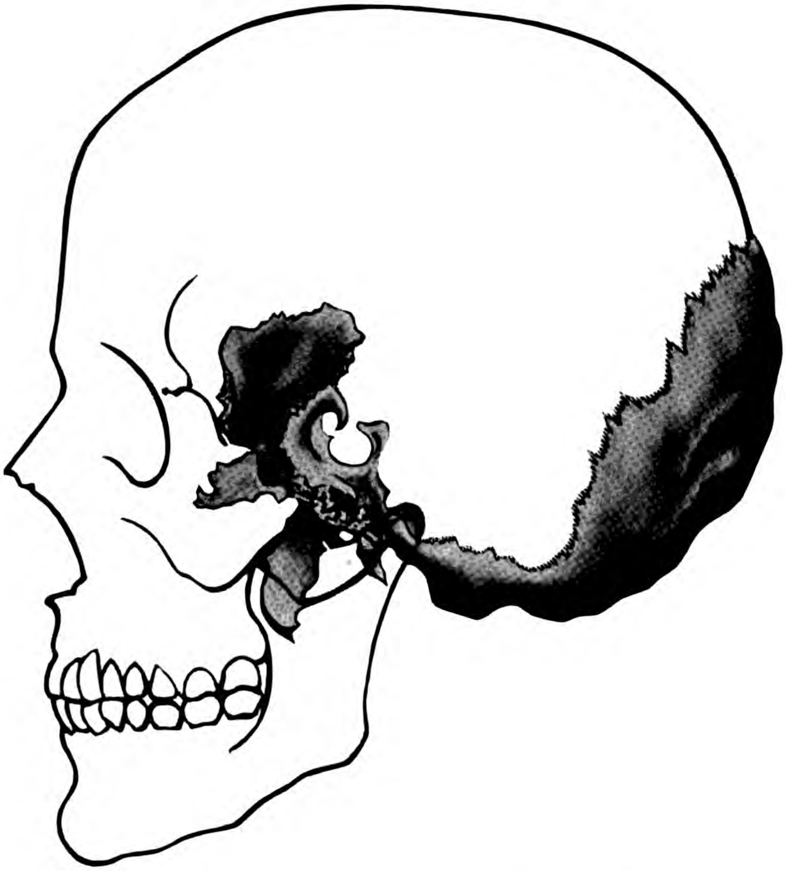
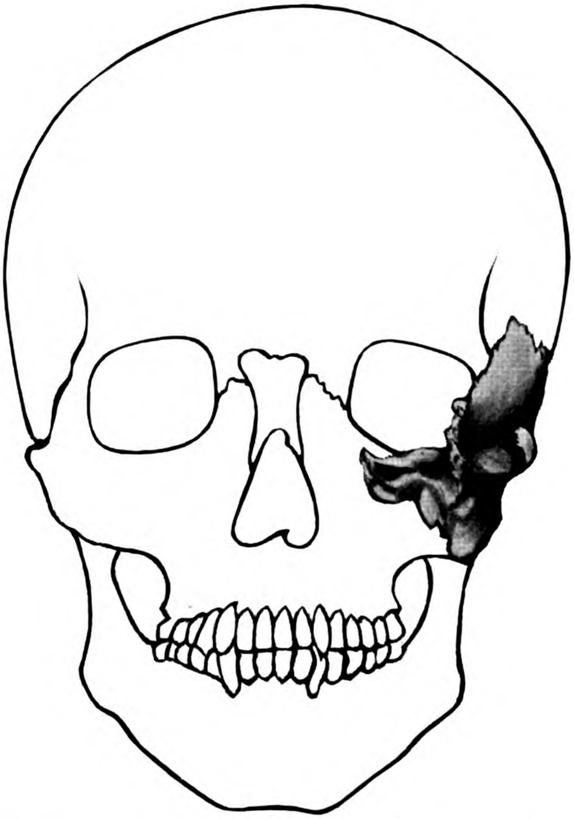


Fig. 234. The Sphenoid and Occipital Bones in Their Relation to the Skull.



The Temporal Bone in Its Relation to the Skull

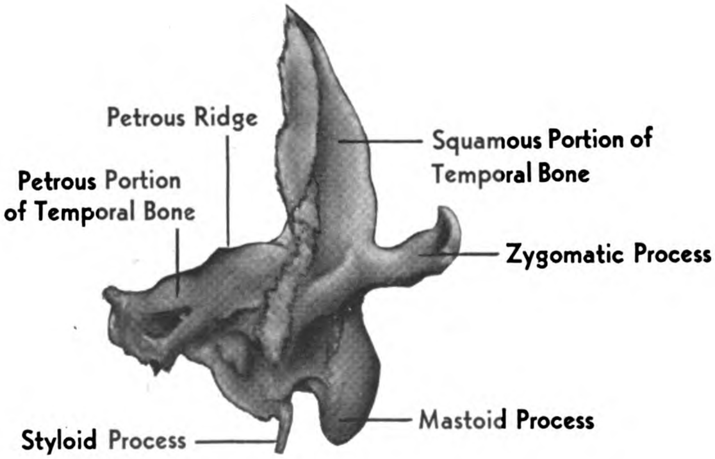
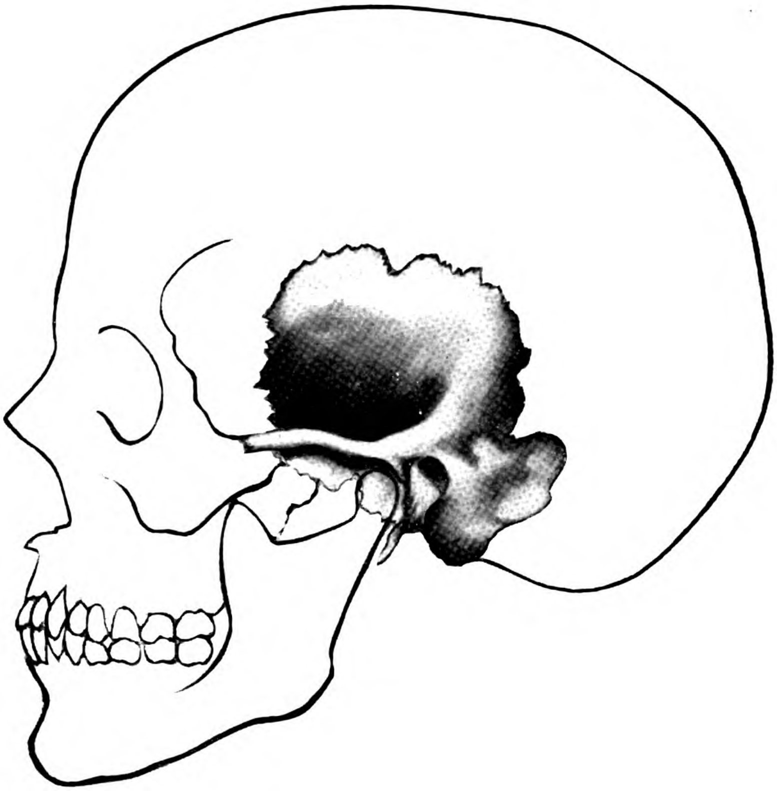

Petrous Ridge
Petrous Portion of Temporal Bone
Squamous Portion of Temporal Bone
Zygomatic Process
Mastoid Process
Styloid Process

Fig. 235. The Temporal Bone—Anterior View.



The Temporal Bone in Its Relation to the Skull

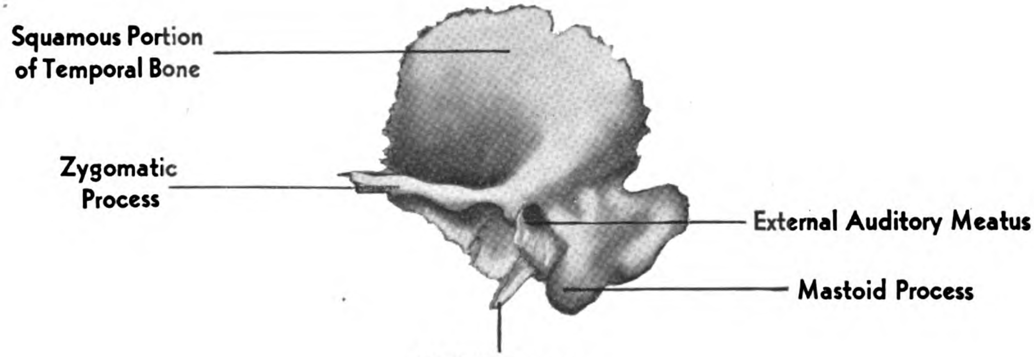


Fig. 236. The Temporal Bone—Lateral View.

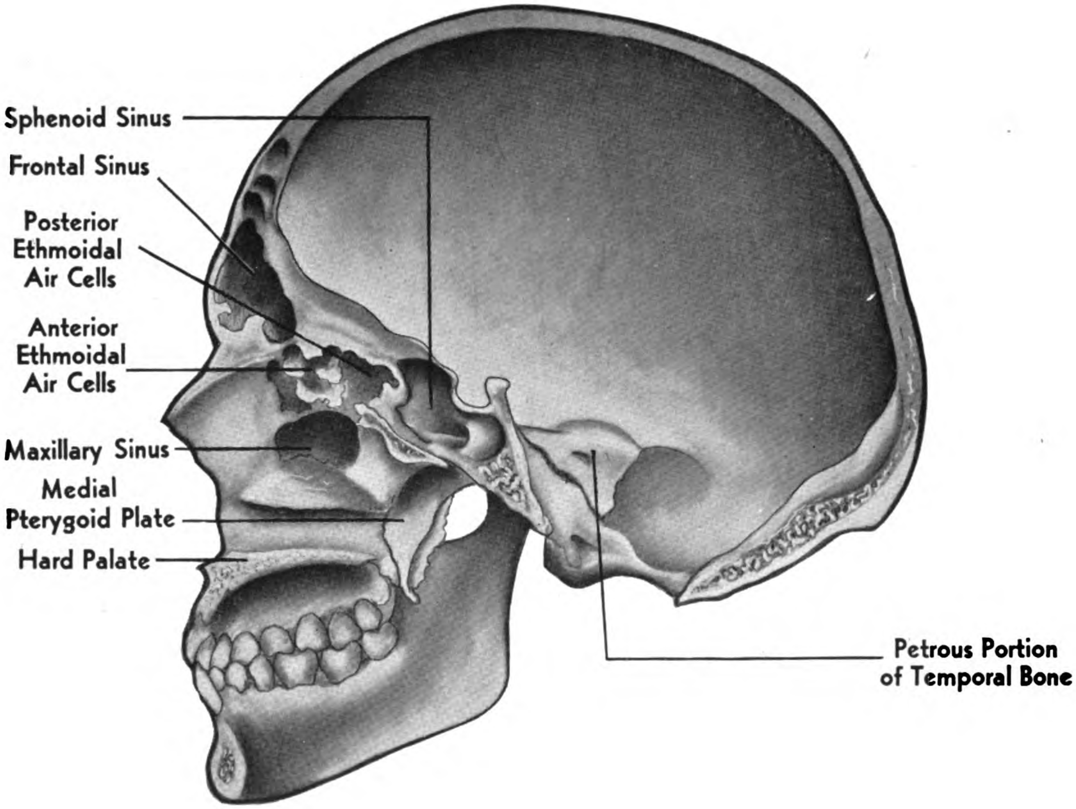

Sphenoid Sinus
Frontal Sinus
Posterior Ethmoidal Air Cells
Anterior Ethmoidal Air Cells
Maxillary Sinus
Medial Pterygoid Plate
Hard Palate
Petrous Portion of Temporal Bone

Fig. 237. The Median View of Right Half of the Skull.

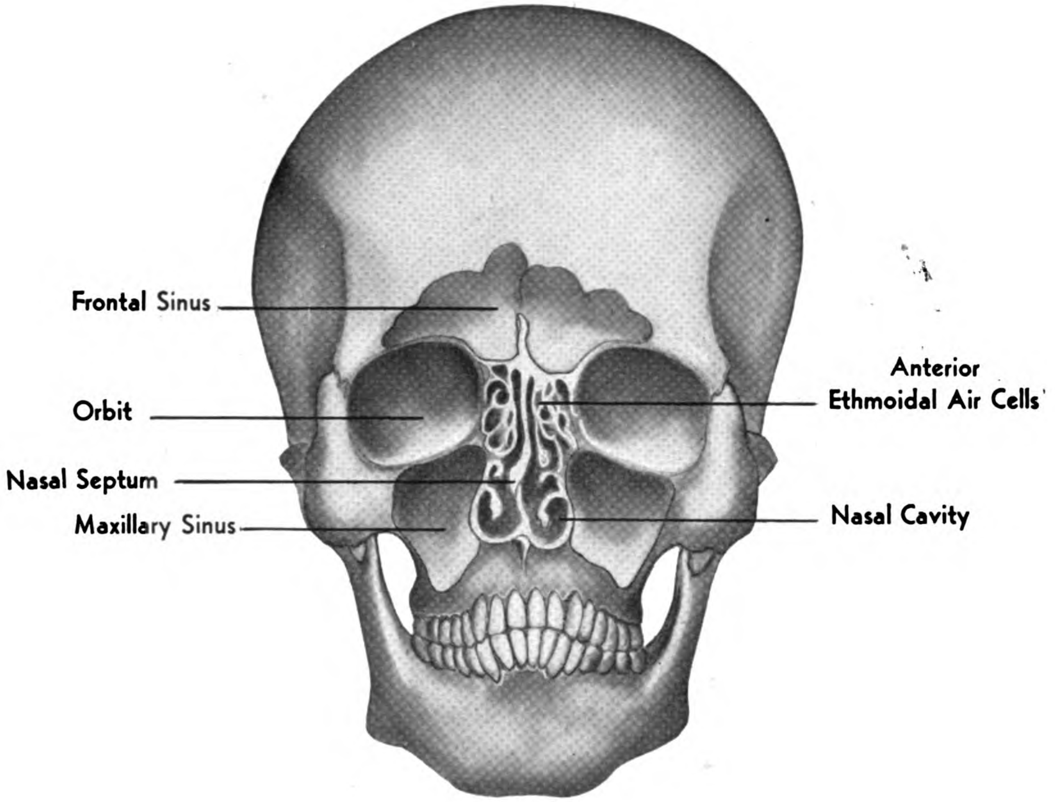


Fig. 238. Semi-diagrammatic View of the Paranasal Sinuses.

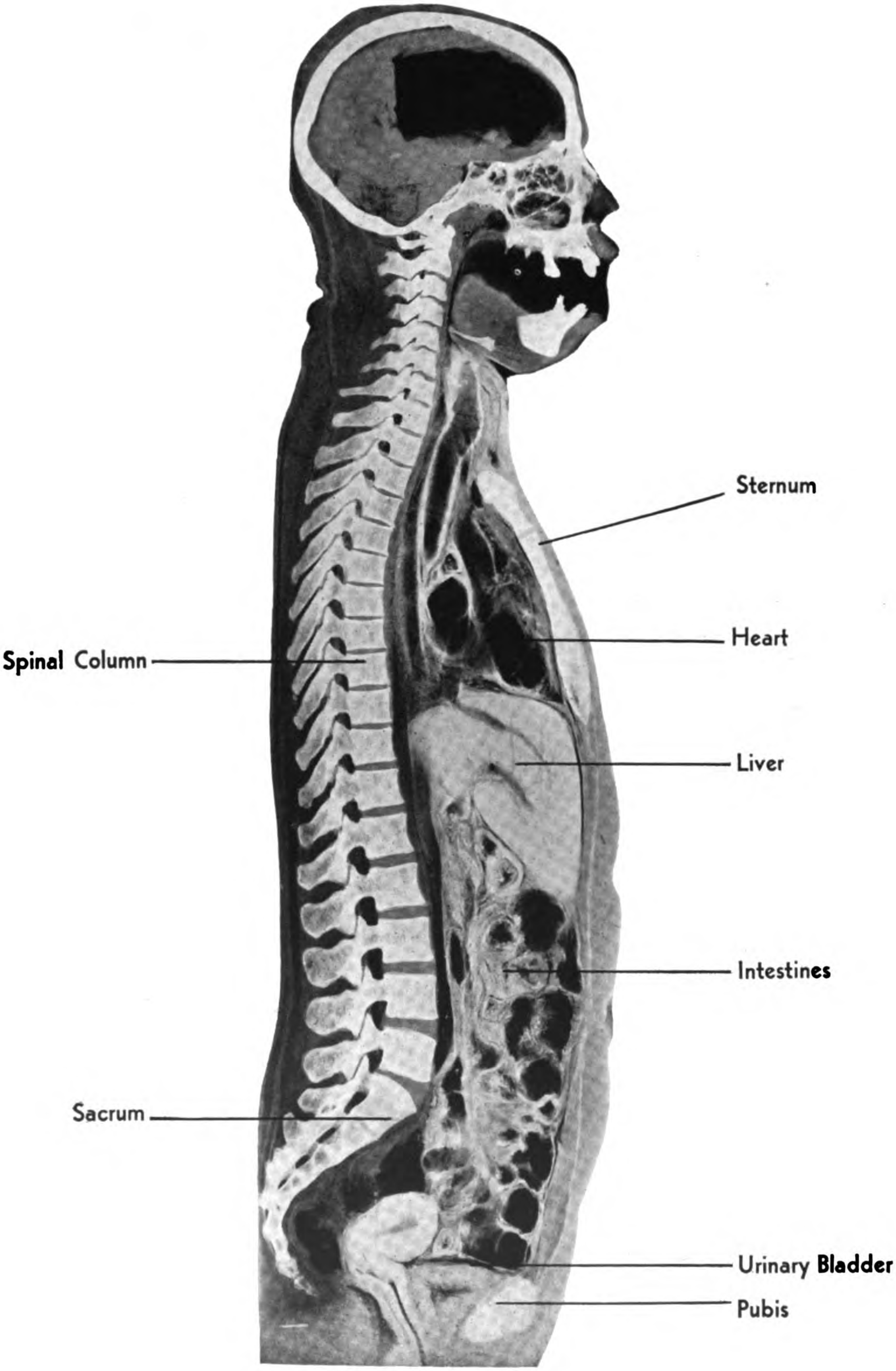


Fig. 239. Sagittal Section of Female Cadaver.

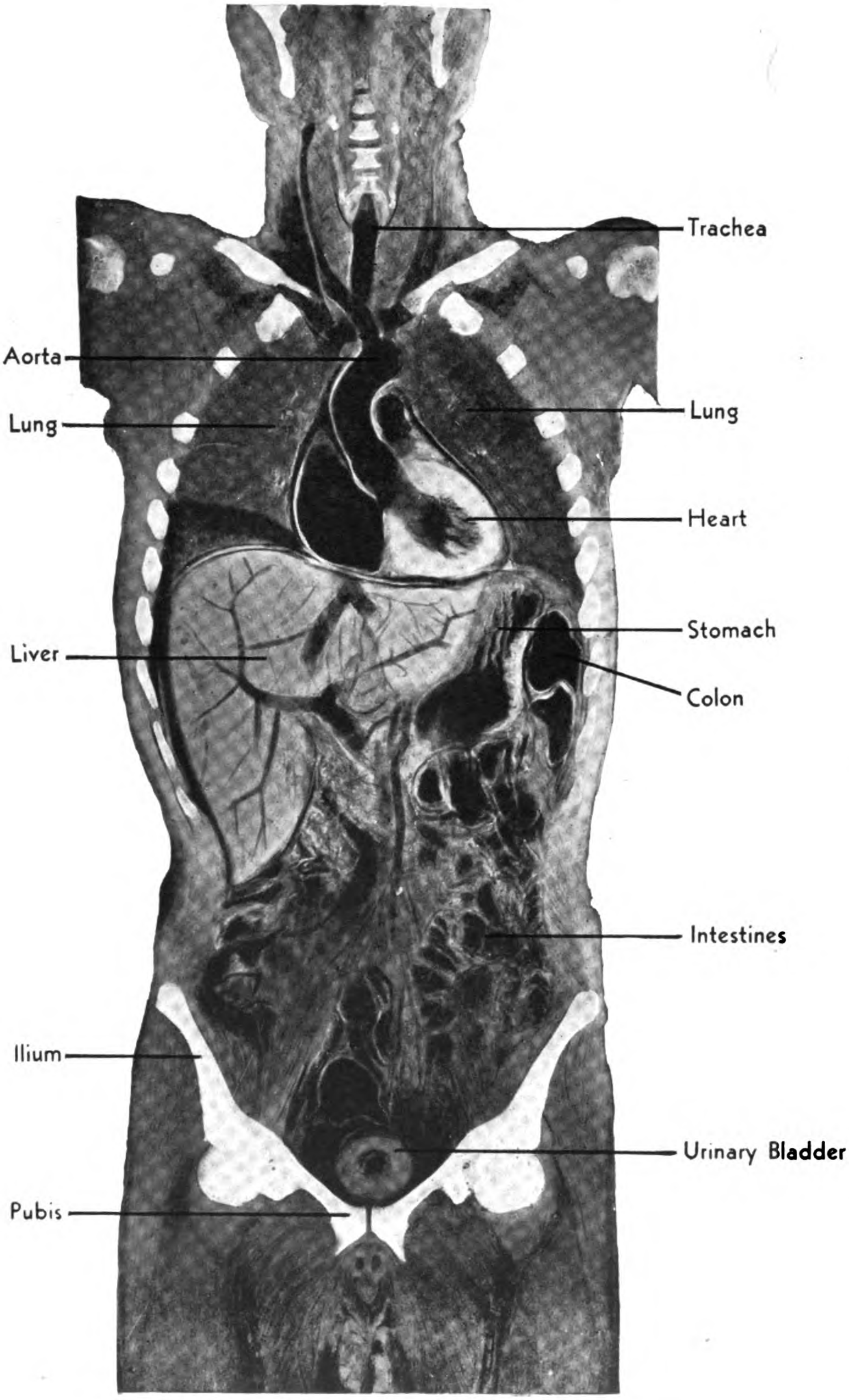


Fig. 240. Coronal Section of Male Cadaver.

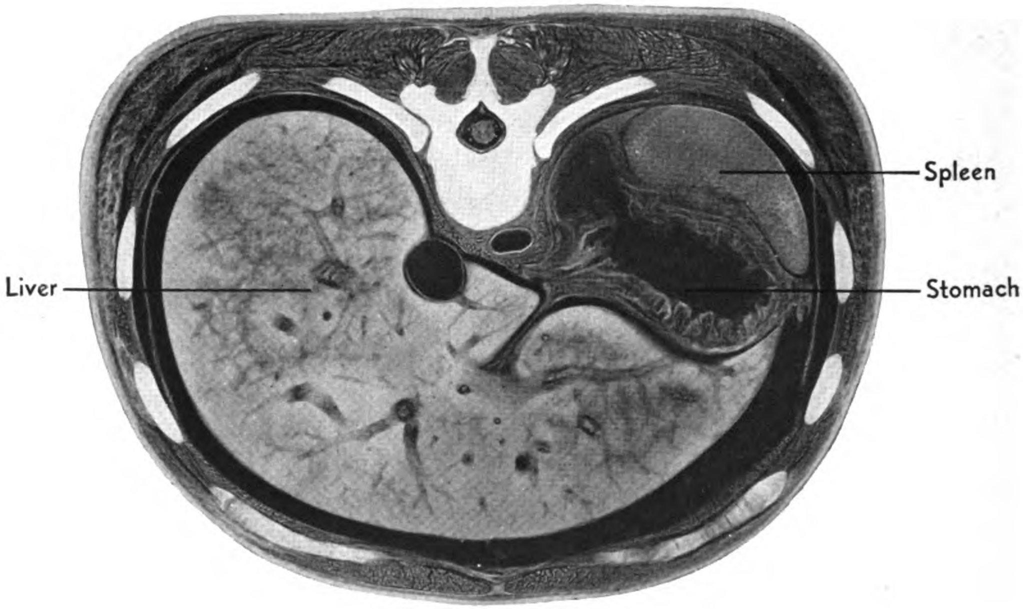


Fig. 241. Transverse Section of Cadaver.

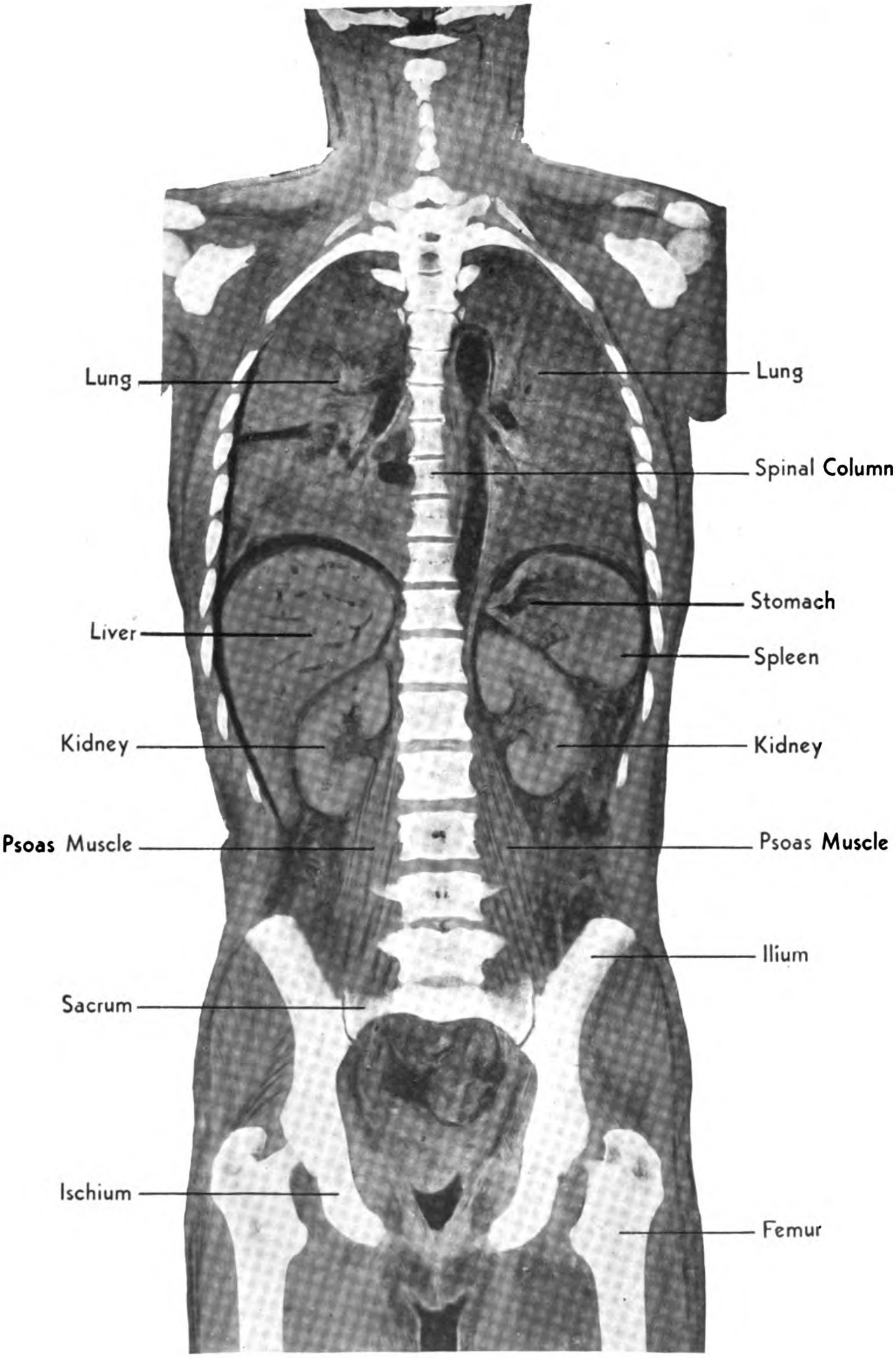


Fig. 242. Coronal Section of Male Cadaver.

CHAPTER XV

Positioning and Technic

GENERAL 204
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A SYSTEMATIC RADIOGRAPHIC PROCEDURE 210
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General

THE various positions shown in the illustrations in this chapter are those generally employed in modern radiography. While a number of angular positions are given, it will be found necessary at times to supplement them with others because of the nature of existing pathology or the condition of the patient.

Angulation of the tube, film, or object must in many instances be approximate. There are few parts of the body in which definite degrees of angulation will produce exactly the same end results. Anatomical variations, both externally and internally, may necessitate changes in angulation of either the tube, film, or object, and in some instances all three of them if maximum results are to be obtained. Experience alone can accurately determine these variations. There can be no set rule.

It is believed that if the technician thoroughly understands the proper positioning of the patient for the usual true lateral, antero-posterior, postero-anterior, and certain established angular positions, little difficulty should be encountered in making such variations as are necessary to meet the requirements. It is well for the technician, with the assistance of the radiologist, to work out a series of such angular positions as may be felt desirable from time to time. The positions as illustrated and described are those most commonly employed in existing x-ray laboratories and are approximately the same regardless of whether a cardboard holder, screens, an inclined plane device, or a Potter-Bucky diaphragm is used.

Anatomical landmarks are essential in the duplication of positions. Those selected for this text or others may be employed. To a certain point it may be considered immaterial what particular landmarks be accepted for the purpose, but some landmark should be selected for each region or position and that landmark carefully placed in relation to the tube and the film.

The size of the film and its position in relation to the part to be exposed is suggested, but both may be altered as conditions or preference requires. The position of the tube in relation to the film or cassette is given. It is usually considered better practice to place the patient in the position required on the film or cassette and then center the tube to the film and not to the patient. This will result in correct alignment of the tube, object, and film.

Every effort has been made to make the illustrations of positions self-explanatory. To do this, several methods were employed to clearly indicate landmarks, angulation, position of patient, direction of the central ray, etc. The use of parts of the skeleton, mirrors, and diagrams are employed for the purpose of aiding the operator to visualize the problems involved. To further augment the information in the illustration, a written description of each position is given.

A reproduction of a radiograph of average quality accompanies each of the radiographic positions illustrated. It must be recognized that this necessary reduction results in a considerable loss of detail and contrast from the original film and that this reproduction does not represent the maximum radiographic quality in comparison to its original. However, each radiographic reproduction in this chapter has been made with the positions as illustrated. Despite the reduction in size, these reproductions give the operator a better understanding of what may be expected from the positions as given.

In connection with each of the radiographic illustrations, certain technical data is presented.

Obviously, x-ray equipment is not self-operating despite the many improvements which time has evolved. It is believed that the information given will aid materially in providing the operator a means of obtaining as nearly as possible the maximum results which the equipment is capable of producing.

Experience seems to indicate that too little attention is paid by the majority of x-ray operators to the problem of producing the maximum diagnostic results based upon existing pathology. Too much attention is paid to the idea of producing so-called "routine" results with technics that stray far from the fundamentals which guide one to consistently good results.

In spite of the many improvements made in x-ray apparatus, there are many instances in which the results produced leave much to be desired. Regardless of how valuable the technic chart may seem to be, it cannot take the place of individual skill and experience, primarily because the patient factor is always an unknown quantity.

Modern x-ray procedures demand that widely different technics may be necessary for the same area if the best diagnostic results are to be produced. There cannot be one particular technic which can be considered best under any and all circumstances. Consequently, technic charts at their best should be considered only as a baseline from which a multiplicity of procedures may be utilized, based upon existing pathology and the area being exposed.

The technical factors given for each area constitute what should be considered a starting point. Because of the many variables in x-ray apparatus itself, which includes a greater or less absorption in the Potter-Bucky diaphragm, variation in speed of screens and films, different darkroom conditions, improper or inaccurate calibration of apparatus, and the ever-present patient factor, it is entirely out of the question to hope that all of the factors given can be utilized as designated.

For the above reasons, using the milliampere-second factor at the distance recommended, the kilovolts peak value may vary as much as plus or minus 10 kilovolts peak, and in some instances more.

It will be noted that centimeter thickness for each part is given. Every effort was made to obtain a subject of average build and tissue opacity.

The "non-screen" procedures were based upon the use of regular x-ray films, and not the so-called "non-screen" or "no-screen" film. If the "non-screen" or "no-screen" film is employed, the milliampere-seconds may be reduced approximately 75 per cent, or the kilovolts peak value reduced 12 to 15 kilovolts peak. The screen procedures are based upon the use of Patterson Parspeed screens.

It is important to bear in mind that there are other considerations which control any specific technic. One of the most important is the x-ray tube, the rating chart of which must be observed in formulating any specific technic. For example, the energizing apparatus available may have a rating higher than the x-ray tube, or the reverse may be true. The specific technic employed must be based upon both tube rating and the equipment rating.

As previously mentioned, the centimeter thickness of each part is given. The variation in kilovolts peak per centimeter is based upon the utilization of regular films without screens and regular films with Patterson Parspeed screens.

It will be noted that the change per centimeter thickness with Parspeed screens varies from 2 to 3 kilovolts peak, depending on the range of kilovolts peak employed.

When a non-screen procedure is used, the average variation per centimeter is 3 kilovolts peak. Some variations in this value may exist, depending upon whether a regular film is being employed for non-screen radiography, or the special "non-screen" film. The difference is comparatively slight, however, and for all practical purposes the variation of 3 kilovolts peak per centimeter may be used in either case.

As previously mentioned, the kilovolts peak variation per centimeter changes depending upon the range of kilovolts peak being employed. This is due to the relative change in screen speed as the kilovolts peak factor is varied.

To simplify technical procedure, the following tabulation of the change in kilovolts peak per centimeter, depending on the basic technic, will be found useful.

If the basic technic used calls for kilovolts peak values between 30 and 40 kilovolts peak, a change of 1 to 1½ kilovolts peak per centimeter is usually required; from 40 to 55 kilovolts peak, 1½ to 2 kilovolts peak per centimeter; from 55 to 70 kilovolts peak, 2 to 2½ kilovolts peak per centimeter; from 70 to 85 kilovolts peak, 3 kilovolts peak per centimeter.

Because comparatively few technical procedures call for kilovolts peak values under 40 kilovolts peak or over 85 kilovolts peak, and because a certain amount of latitude exists in almost every type of work, a good rule to remember in general is that for those areas of the body requiring comparatively low kilovolts peak values, 2 kilovolts peak per centimeter will be found satisfactory. For those areas of the body such as the lateral lumbar spine, etc., which require higher kilovolts peak values, 3 kilovolts peak per centimeter will be found more nearly correct.

One of the greatest difficulties in the consistent production of diagnostic results is the variation in actual tissue opacity between individuals. That is, even though the part be carefully measured, there may be a difference of 10 kilovolts peak or more for a given thickness of part.

Aside from certain pathological conditions, it is well known that a fleshy individual would be considered less opaque than a muscular individual, even though their measured thickness is the same. Older individuals, generally speaking, are much less opaque to radiation than younger people. Wherever atrophy is present, regardless of the cause, the general tissue opacity is less than when such a condition is not present.

The kilovolts peak factor should be employed as a compensating factor for these variations in tissue opacity. Inasmuch as the kilovolts peak factor is the only one which changes the quality of radiation, the best results are ordinarily obtained by compensating for tissue opacity by changing kilovolts peak.

Regardless of the procedure employed, certain areas of the body may be particularly affected by respiration. These comparatively few areas include the chest in all positions, heart, lateral dorsal spine, ribs, shoulder, etc. In these areas the total density on the film would be materially increased at inspiration and materially reduced at expiration. A difference of as much as 10 to 15 kilovolts peak may be required between inspiration and expiration in order to maintain density. Likewise, contrast will be generally affected. Usually greater contrast will result regardless of procedure, if the exposure is made at inspiration. In those areas wherein the thickness of part is materially affected by respiration, measurement should always be made at full expiration, never inspiration.

Because of the motion of the diaphragm during respiration, certain organs of the body such as the stomach, gall bladder, etc., change position between inspiration and expiration.

Areas of the body such as the antero-posterior lumbar spine, kidney, etc., will be benefited materially if a compression bag in addition to an immobilizing band is used. When the compression bag is employed, particularly in the case of fleshy or fat individuals, a reduction of as much as 10 to 15 kilovolts peak may be necessary to obtain the desired density. Obviously, reducing the kilovolts peak to this extent will materially improve contrast. Therefore, in measuring the thickness of part for such areas, the result of compression must receive consideration.

Probably no factor causes as much difficulty as motion of the part during exposure. In order to reduce the danger of motion as far as possible, immobilization should always be utilized when practical. Only a few of the illustrations show the immobilizing band in place, despite the fact that it should be employed in many of them.

The reason for this is to provide a more understandable view of the subject. The text accompanying each radiograph designates those areas in which compression and immobilization, or both, are recommended.

In general, measurement of part thickness should be made between the point of entry and exit of the central ray.

The use of cones is almost a necessity for certain areas of the body, particularly the heavier parts, and should always be employed when practical. However, the use of cones or any method whereby the port of entry is limited, makes necessary certain changes in the technical procedure. The smaller the port of entry, other factors remaining the same, the greater the amount of energy required, and the larger the port of entry, other factors remaining the same, the less the amount of energy required.

In general, it is advisable to change penetration to compensate for the use of cones. This increase, under certain conditions, may be as much as 10 kilovolts peak. Cones are recommended with and without the Potter-Bucky diaphragm.

To change a Potter-Bucky diaphragm procedure to one without, either deduct approximately 15 kilovolts peak, or use one-fourth the milliampere-seconds. To reverse the procedure, add 15 kilovolts peak, or use four times the milliampere-seconds. The above values depend upon the ratio and absorption of the Potter-Bucky diaphragm in use, as well as the basic technic, and therefore must be considered approximate.

In many instances the focal-film distance given in this chapter will be found impractical. This applies especially to the longer distances such as 40 inches. If the focal-film distance is decreased, it is advisable to reduce milliampere-seconds to compensate for density. Thus, for the lateral skull with the Potter-Bucky diaphragm, if the focal-film distance is 30 inches instead of 40 inches, the milliampere-seconds (usually exposure time) is reduced approximately 40 per cent.

A means of identification is considered essential to designate the right and left sides and whatever additional information is desired. There are many varieties of film markers available for this purpose.

Infants and Children

Radiography of infants and children under five years of age presents a real problem to even the most experienced operator. This applies particularly to infants because of negative patient co-operation. Because of the lack of co-operation, the factor of motion must receive more attention than for other types of radiography.

The time of exposure must be such that loss of detail due to motion is reduced to the minimum, this in spite of the fact that it may be necessary to sacrifice contrast to a greater or less extent, depending upon the apparatus and x-ray tube available. For a given exposure time, high powered equipment (500 milliamperes) will make possible a better end result than low powered equipment (30 to 100 milliamperes). This is because a higher milliamperage can be employed with a correspondingly lower kilovolts peak value.

Regardless of equipment and tube capacity, the technical factors employed should be based upon exposure values not in excess of 1/10 second, if at all possible. There are exceptions, of course, where 2/10 or even 3/10 second can be used, but in general such exposure values will result in objectionable loss of detail due to motion.

It will be noted that for radiography of adults, a milliampere-second procedure is given. For infants this is not practical. Milliamperage and time of exposure must be divided and the time factor adjusted to the shortest practical exposure time, that is, sufficiently short to obviate the danger of motion.

The milliampere factor depends primarily on the capacity of the energizing apparatus and tube rating. The higher the milliamperage the less the kilovolts peak, which will result in increased contrast. Because of the necessarily short time of exposure, the degree of contrast obtainable is somewhat limited.

The distance factor can be of material aid in providing better contrast. In general, the object-film distance for infants is less than for adults. Therefore, closer focal-film distances can be employed when necessary to make possible lower kilovolts peak values. This applies particularly to low and median powered apparatus.

Screens are usually employed for all regions, except when 200 to 500 milliampere apparatus is available, in which case radiography without screens is practical for the thinner extremities.

The special "non-screen" film can be used to an advantage for extremities because of the lower kilovolts peak or faster time in comparison to regular film without screens.

If the apparatus available includes a "speed" bucky diaphragm or a stationary grid, and sufficient power is provided, better results will be obtained through their use in spite of the increase in kilovolts peak made necessary through the use of the grid.

Except for extremities, cones should be used.

Tissue opacity of infants is different from that of adults. In general, the chest of infants per centimeter thickness is more opaque than the average adult chest. On the contrary, the skull, extremities, abdomen, etc., are less opaque. Consequently, a separate procedure for infants must be used.

Tissue differentiation is considerably less. To provide satisfactory contrast, the kilovolts peak value should be as low as possible. One of the main reasons for lack of contrast in this type of work might be termed over anxiety on the part of the operator to "be sure" of obtaining something, at least, by over penetrating and under development.

As a guide, the following technics may be of value:

Extremities: 50 milliamperes, 1/10 second, 30-inch distance, 35 to 50 kilovolts peak

Chest and Heart: 100 milliamperes, 1/20 second, 36-inch to 40-inch distance, 45 to 60 kilovolts peak

Abdomen (not including spine) and Skull: 100 milliamperes, 1/10 second, 30-inch distance, 45 to 60 kilovolts peak

Spine: 50 to 100 milliamperes, 1/10 second, 30-inch distance, 45 to 70 kilovolts peak

The above values are with intensifying screens, and without Potter-Bucky diaphragm. Suitable compensation is to be made when the Potter-Bucky diaphragm or stationary grid is used.

Even though higher capacity equipment is available, kilovolts peak values below 35 are not advisable except for a direct soft tissue procedure. Kilovolts peak values below 35, even for the thinnest extremities, results in a procedure which has very little latitude, and the chance of error is materially increased.

To decrease the possibility of motion in this type of work, it is important that the operator make all necessary machine settings and then delay the exposure, if necessary, until the patient quiets down. Obviously, it is necessary to watch the patient until this period occurs. The "quieting down" period is purely relative, but a little added time often is the difference between a single exposure and several re-takes.

Preparation of the Technic Chart

The first consideration in the establishment of specific technical factors (milliamperage, time, distance, kilovolts peak) is the apparatus available. For example, capacity of generator and x-ray tube, focal-film distance obtainable, processing room conditions, etc.

The factors of milliampere-seconds and distance presented with the illustrations are based upon what is generally accepted as satisfactory contrast and will be used as constants in the preparation of the chart. The kilovolts peak value will be used as the variable factor in controlling density.

As a starting point or guide, the kilovolts peak value as given in the charts should be used. For example, the extremity group is the most convenient as a starting point. As the first illustration is of the hand, postero-anterior, this region will be used for the specific procedure to be employed.

The factors recommended for this region are as follows: Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 44 kilovolts peak. The equipment available is a full wave 200 milliampere generator and a double-focus tube, the focal spot sizes of which are 2.2 millimeters and 5.2 millimeters. Of the two focal spots, the small one is always the one of choice, provided motion can be controlled, within the time and milliampere limits which are established by the tube rating chart, bearing in mind that the specific milliampere and time factors to be chosen will be used for the entire extremity group.

Referring to the tube rating chart, it will be noted that 100 milliamperes for 1 second (100 milliampere-seconds) at 46 kilovolts peak could be used. The rating chart referred to usually accompanies each tube, and should be followed. The factors given are only examples. However, if this procedure were chosen, it would be limited to only the thinnest extremities, but it is preferable to establish uniform milliampere and time values for the entire extremity group, and further a technic chart should never be established at maximum tube ratings.

To cover the entire extremity group, 50 milliamperes for two seconds (100 milliampere-seconds) is well within tube limits, and will be the specific factors for this group.

The specific factors for the hand, postero-anterior, as given is: Without screens, without-Potter-Bucky diaphragm, 50 milliamperes, 2 seconds, 44 kilovolts peak, 40-inch distance. In some instances, a distance of 40 inches is not obtainable, in which case the maximum permissible distance should be employed, and the kilovolts peak or milliampere-seconds reduced accordingly.

The next step is to measure part thickness. Referring again to the factors recommended, it will be noted that they are based upon a part thickness of 3 centimeters, and further, the variation in kilovolts peak per centimeter for this part is 3 kilovolts peak. This does not mean that it is necessary for a 3 centimeter hand to be used. If in preparation of the chart, the hand, or any other region, differs in centimeter thickness from that shown, compensation can be made by changing the kilovolts peak accordingly. Instead of 3 centimeters, the hand of the subject employed may have a thickness of 4 centimeters, in which case the starting kilovolts peak should be 47 instead of 44.

Assuming that the above is true, the specific factors will be as follows: 50 milliamperes, 2 seconds, 40-inch distance, 47 kilovolts peak, part thickness 4 centimeters.

Positioning the region according to the illustration and its description, the first exposure is made. The problem is to find by experiment the kilovolts peak value which will produce the desired density, keeping milliampere-seconds and distance constant. This first exposure must of necessity be considered a trial exposure. The result will be either too light in density, too dark, or correct.

After the desired density is obtained, and providing the resultant contrast is satisfactory, the kilovolts peak value is charted, and is the baseline technic for this region.

The procedure without screens is desirable for all extremities except knee and shoulder, or most regions not exceeding 10 centimeters in thickness. For regions of greater opacity, the kilovolts peak necessary may cause objectionable secondary fog.

If the special "non-screen" film is employed, radiography without screens can be greatly extended due to the decrease in kilovolts peak made possible through its use.

In addition to procedures without screens, it is advisable to have a so-called "emergency" technic available. Because the possibility of motion is greater in such cases, the time of exposure must be reduced. This reduction in exposure time is accompanied by a lower milliampere-second value. Consequently, to provide for acceptable quality, intensifying screens must be used. The time value is usually 1/20 or 1/10 second, the milliamperes from 100 to 200. Due to the higher milliampere value, the large focal spot should be used.

Having established the technic without screens for the hand, the procedure with screens will be established in the same manner. For example, the factors given are 5 milliampere-seconds, 40-inch distance, 38 kilovolts peak, thickness of part, 3 centimeters.

To establish the milliampere and time factors, reference is again made to the tube rating chart. While 100 milliamperes for 1/20 second (5 milliampere-seconds) could be used for the average thickness even with the small focal spot, the maximum kilovolts peak rating is not sufficient to cover the entire extremity group for all sizes of subjects. Thus, if 1/20 second at 100 milliamperes (5 milliampere-seconds) is chosen, the large focal spot is advised. However, if 1/10 second at 50 milliamperes (5 milliampere-seconds) is to be used, the small focal spot may be employed.

Assuming that the postero-anterior hand is the same thickness as in the procedure without screens, namely, 4 centimeters, approximately 40 kilovolts peak will be used instead of a starting point of 38 kilovolts peak.

The time of exposure, 1/20 second at 100 milliamperes (5 milliampere-seconds), the distance, 40 inches, are then established, and the specific starting technic is: 100 milliamperes, 1/20 second, 40-inch distance, 40 kilovolts peak.

Again, the solution of the problem is to find the kilovolts peak value which will produce the desired density, and when found, is the baseline technic for this region, with screens.

To complete the technic chart for the extremity group, the charted procedure for the postero-anterior hand is used as a guide. For example, assume that the kilovolts peak value decided upon in the technic without screens for the hand is 6 kilovolts peak higher than the suggested starting kilovolts peak, the screen technic decided upon is 4 kilovolts peak higher.

Under such conditions, 6 kilovolts peak should be added to all suggested extremity technics without screens, and 4 kilovolts peak to all extremity technics with screens.

Just as the hand was used to establish a baseline technic for the extremity group, the lateral skull is recommended for the head group, the pelvis for the spine group, the postero-anterior chest for various other positions of the chest and heart, the antero-posterior kidney for abdominal work, etc. Whatever variation in kilovolts peak is found necessary from the starting values given for the above regions, the same correction in kilovolts peak should be made for the other regions in each group.

Although this method will not fit every requirement, since individual preferences differ in respect to density and contrast for particular regions, it will serve as an excellent guide in establishing a baseline technic chart. From this chart, the operator may formulate what might be termed a "tailor-made" procedure, making such changes as may be deemed necessary to produce the maximum diagnostic quality for each region, depending upon individual desires. If the contrast is too great, the milliampere-seconds must be reduced and the kilovolts peak increased to maintain density. To increase contrast, the reverse is true.

A Systematic Radiographic Procedure

Preliminary Steps

1. Determine part to be radiographed
2. Prepare patient, but do not position part at this time
3. Determine if screens, no screens, or "non-screen" films are to be used
4. Determine the number and size of film to be used, and have conveniently available.

Control Stand Factors

5. Adjust voltage compensator
6. Set autotransformer to the approximate kilovolts peak (consult technic chart)
7. Set timer to desired time
8. Set ammeter to give desired milliamperage

Table Controls and Final Positioning of Patient

9. Select proper cone and attach to tube carriage
10. Place film in bucky tray or on table and place identification marker on film holder
11. "Cut-in" bucky interlock (if necessary)
12. Adjust timer bucky mechanism
13. "Cock" bucky
14. Inform patient of what is to be done
15. Measure part thickness
16. Position patient to film
17. Position tube to film
18. Immobilize patient

Final Steps

19. Correct kilovolts peak to part thickness or other determining factors
20. Give patient final instructions
21. Make exposure
22. Release immobilization and make patient comfortable
23. If no more radiographs are to be taken, assist the patient off the table
24. Process film

General

25. The patient should not be made to hold any position longer than necessary.

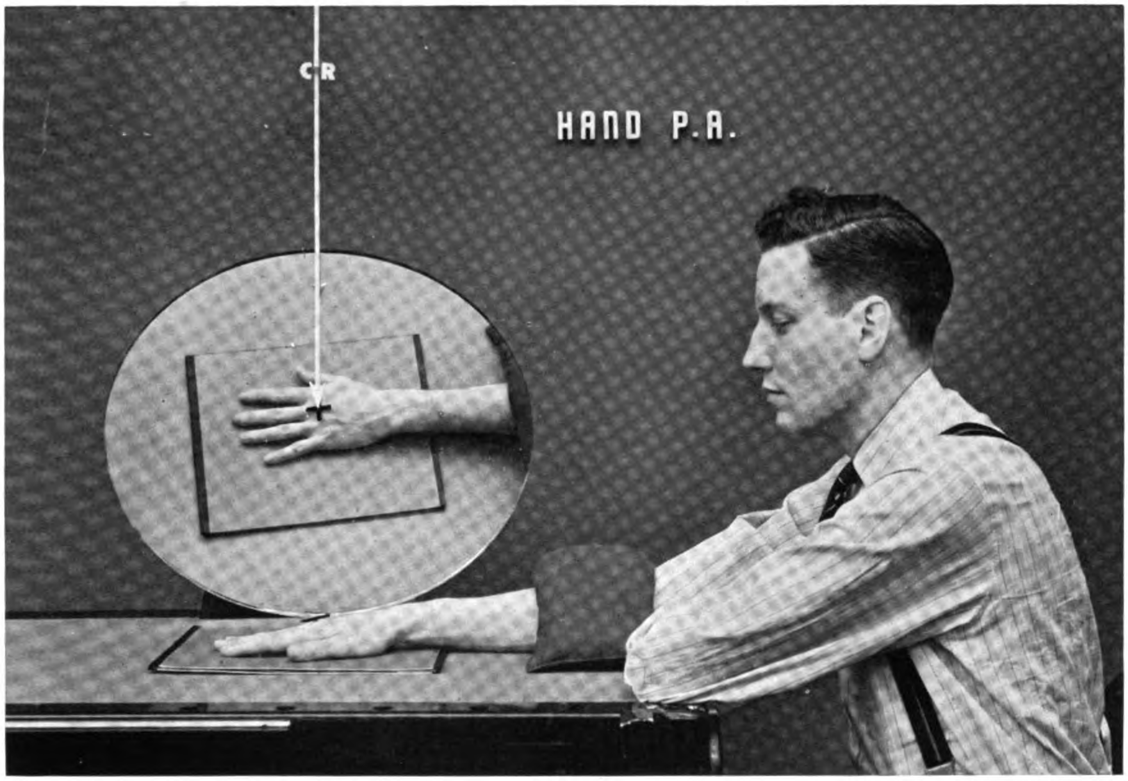


FIG. 243a

Hand, Postero-Anterior

The hand is placed upon the film holder with the palmar surface down, and with the distal end of the third metacarpal bone over the center of the film holder. The wrist is elevated until the palmar surface rests against the film holder, and a sandbag is placed over the forearm to immobilize the hand. The central ray is directed to the center of the film holder.

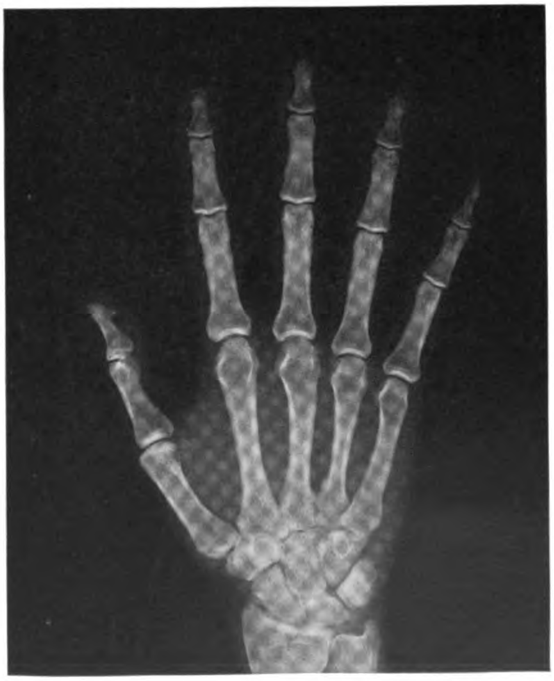


FIG. 243b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—3 centimeters
- Average variation in kilovolts peak from minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the hand is in a dry cast add 5 kilovolts peak
- If the hand is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere seconds, 40-inch distance, 44 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 38 kilovolts peak

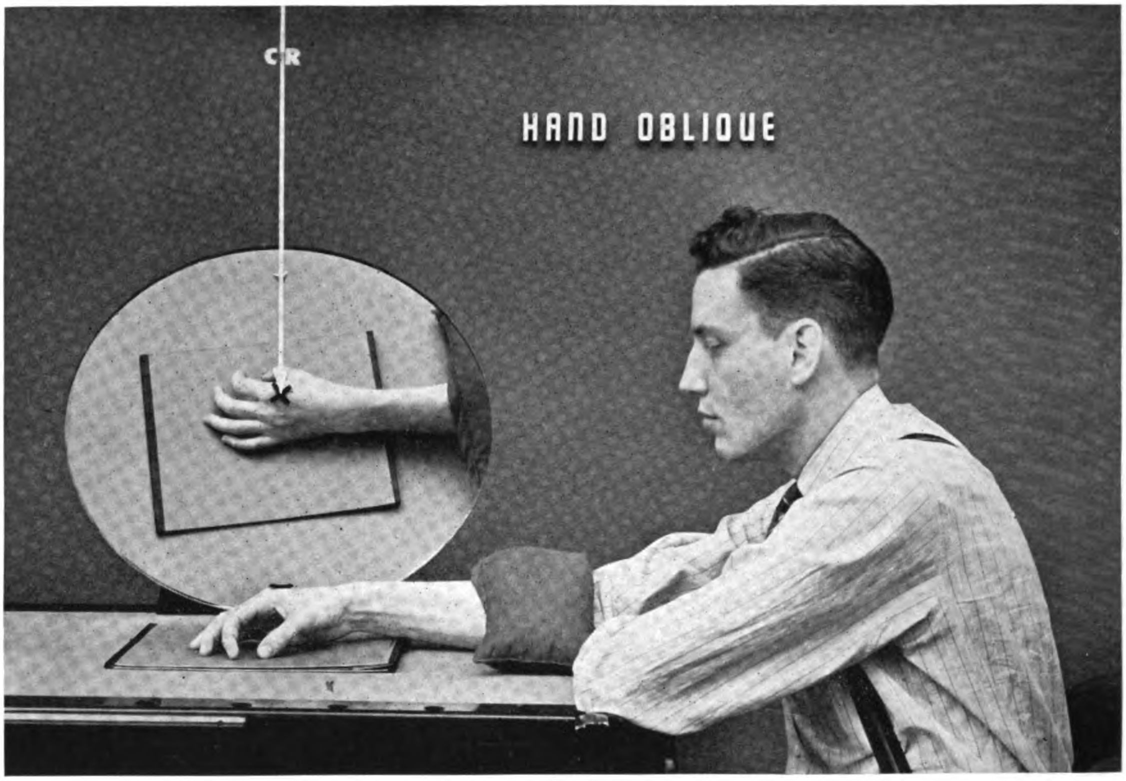


FIG. 244a

Hand, Oblique

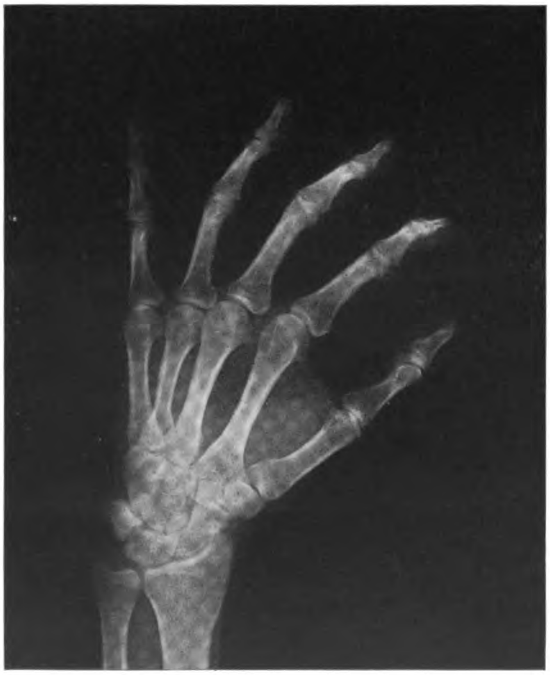


FIG. 244b

The oblique position is attained by rotating the hand medially from the lateral position until each finger tip touches the cassette or exposure holder. The distal end of the second metacarpal is placed over the center of the film, and a sandbag is placed over the forearm. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—4 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 47 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 40 kilovolts peak

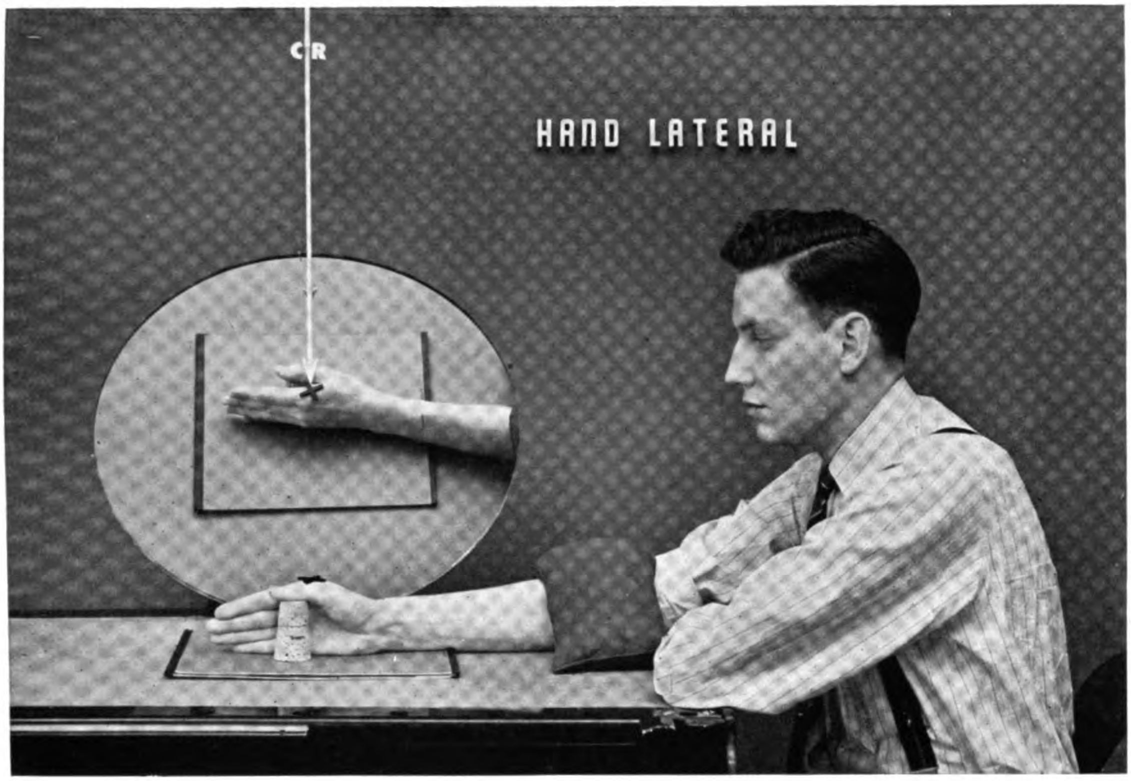


FIG. 245a

Hand, Lateral

With the forearm resting on the top of the table, the hand is placed in the lateral position with the distal end of the second metacarpal bone over the center of the film. For immobilization, the thumb may be supported by a non-opaque material and a sandbag is placed over the forearm. The central ray is directed to the center of the film holder.

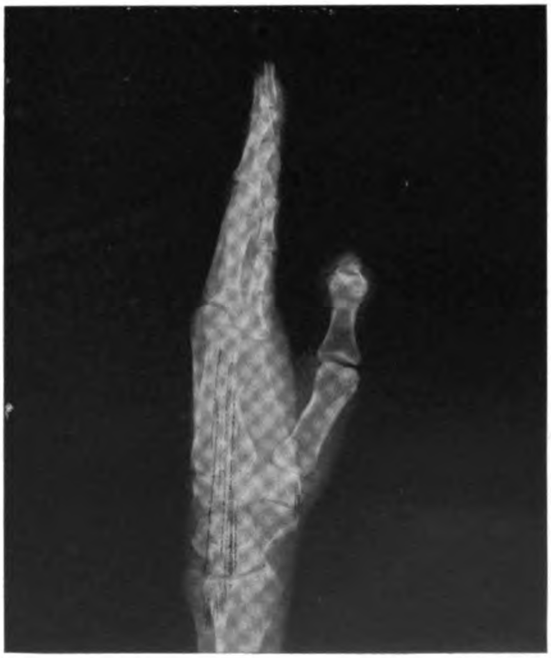


FIG. 245b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—6 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 53 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 44 kilovolts peak

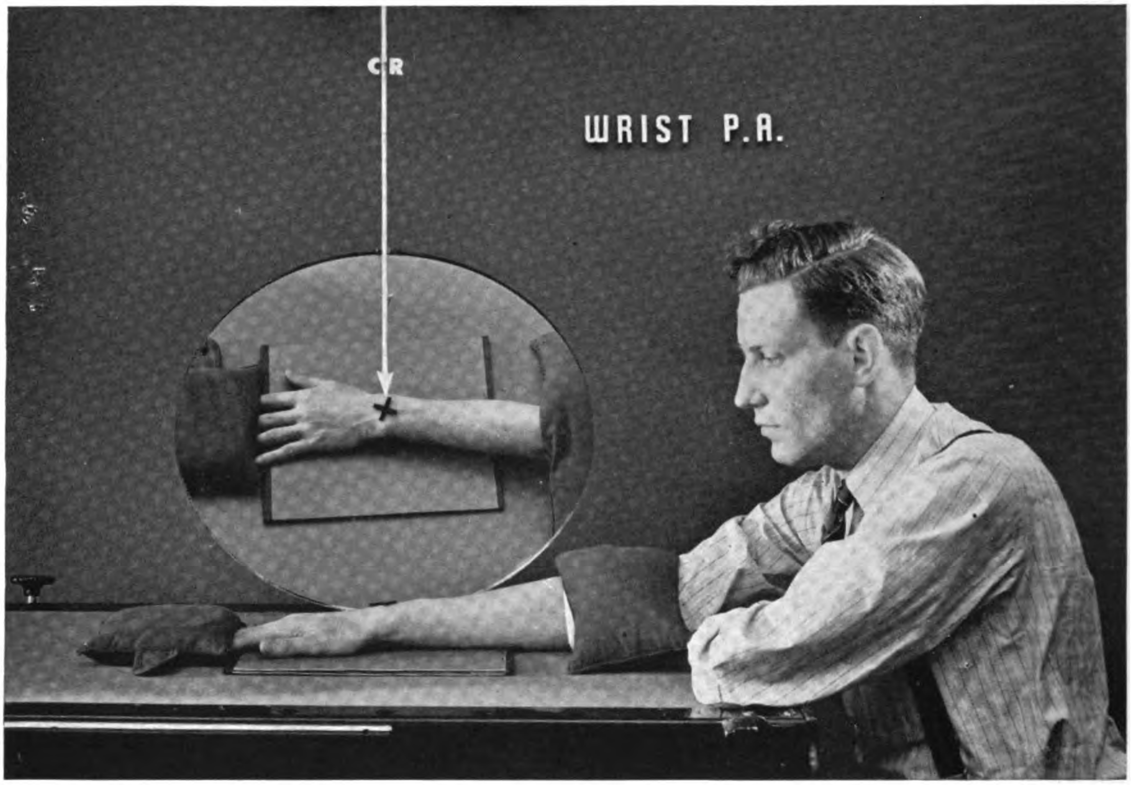


FIG. 246a

Wrist, Postero-Anterior

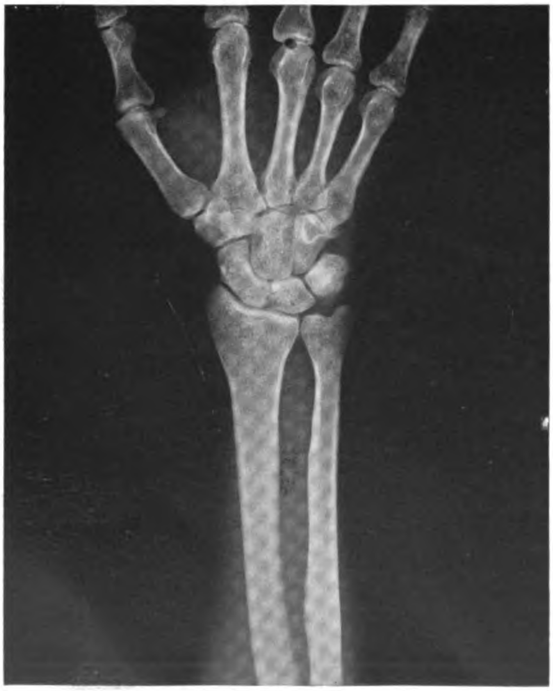


FIG. 246b

The forearm is placed on the table with the palmar surface of the hand down. The wrist is centered to the film by placing the midpoint between the styloid processes over the center of the film holder and is immobilized by using sandbags over the forearm and finger tips. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—4 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the wrist is in a dry cast add 5 kilovolts peak
- If the wrist is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 47 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 40 kilovolts peak

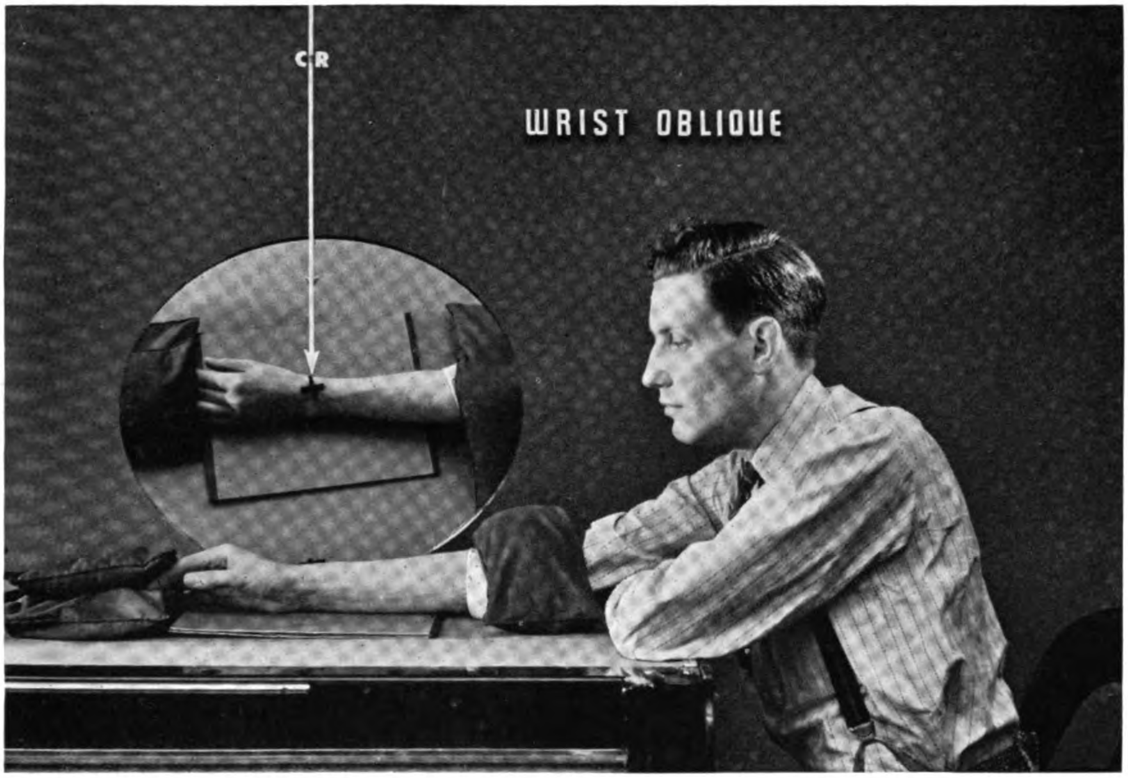


FIG. 247a

Wrist, Oblique

The wrist is rotated medially from the lateral position until it assumes an angle of 45 degrees with the film holder. The midpoint between the styloid processes is placed over the center of the film and sandbags are placed over the forearm and fingers to immobilize the part. The central ray is directed to the center of the film.

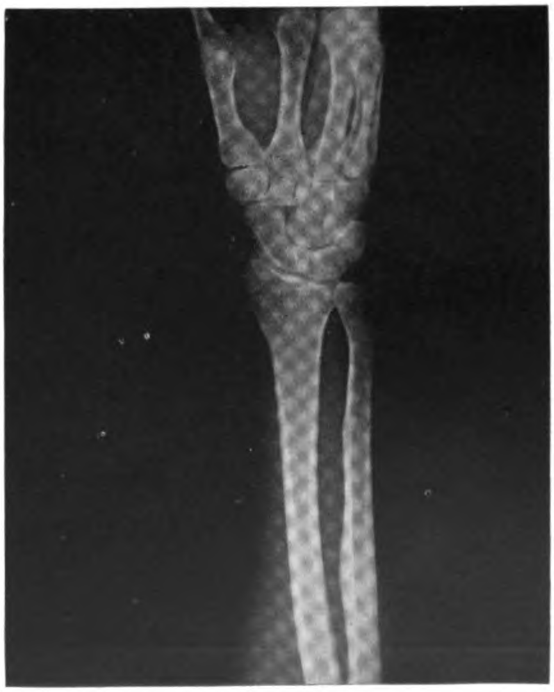


FIG. 247b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—5 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the wrist is in a dry cast add 5 kilovolts peak
- If the wrist is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 50 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 42 kilovolts peak

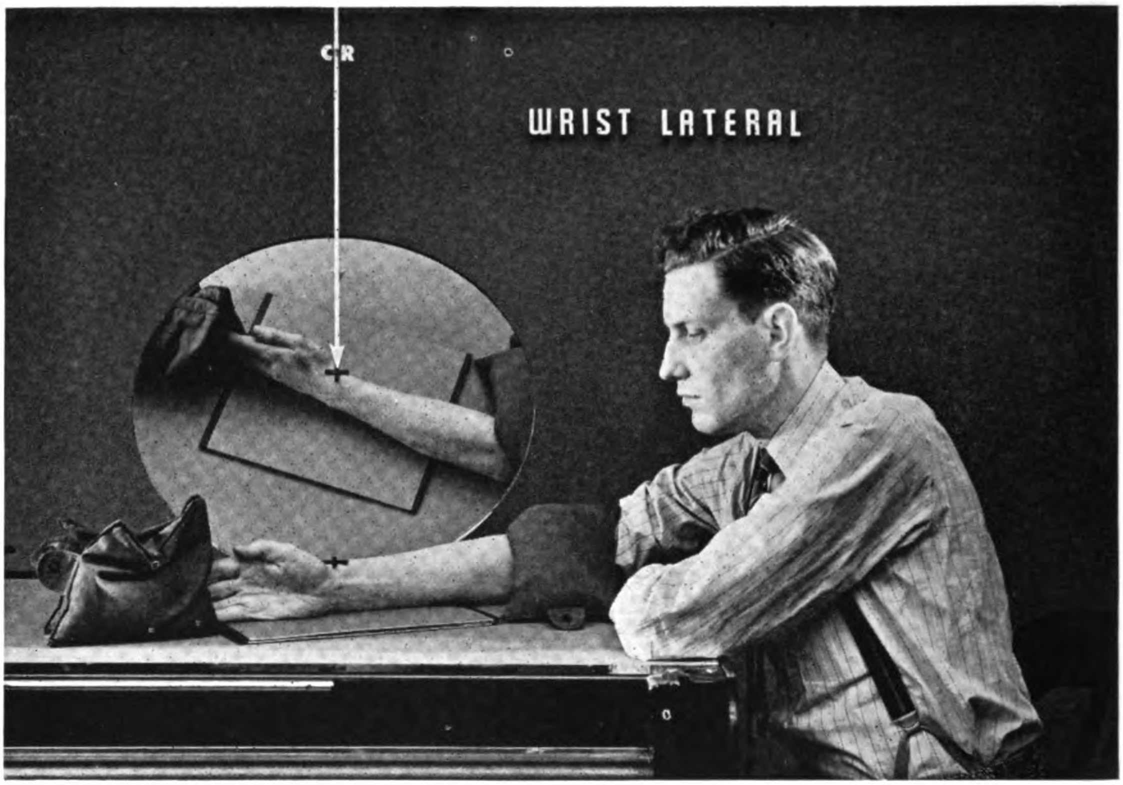


FIG. 248a

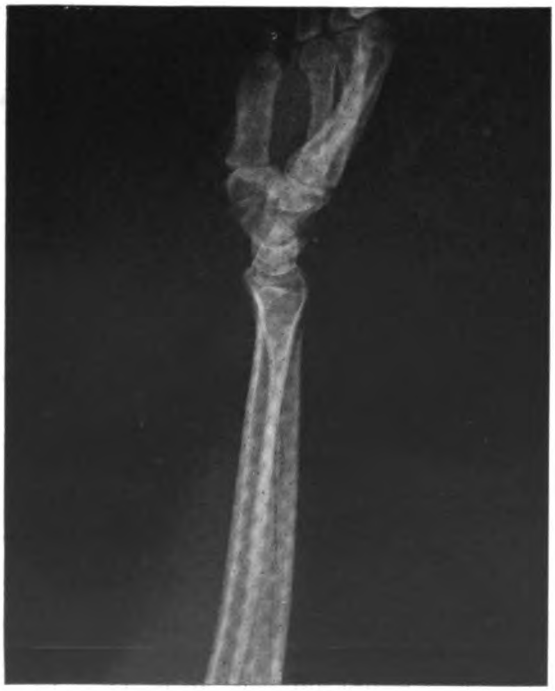


FIG. 248b

Wrist, Lateral

The forearm is placed on the table laterally, with one sandbag over the forearm, and sandbags against the fingers for immobilization. The styloid process of the ulna is placed over the center of the film, and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—6 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the wrist is in a dry cast add 5 kilovolts peak
- If the wrist is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 53 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 44 kilovolts peak

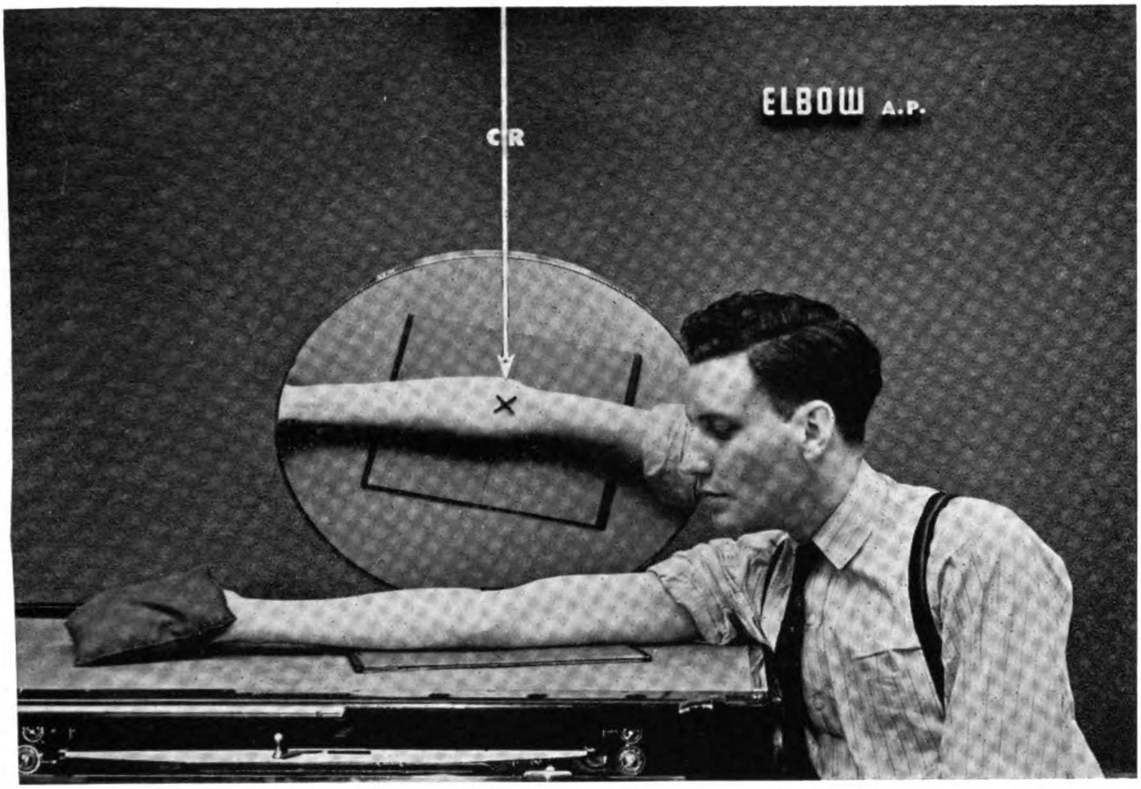


FIG. 249a

Elbow, Antero-Posterior

The back of the arm and forearm are placed against the film holder and a sandbag is placed upon the hand. The midpoint between the epicondyles is placed over the center of the film and the central ray is directed to the center of the film.

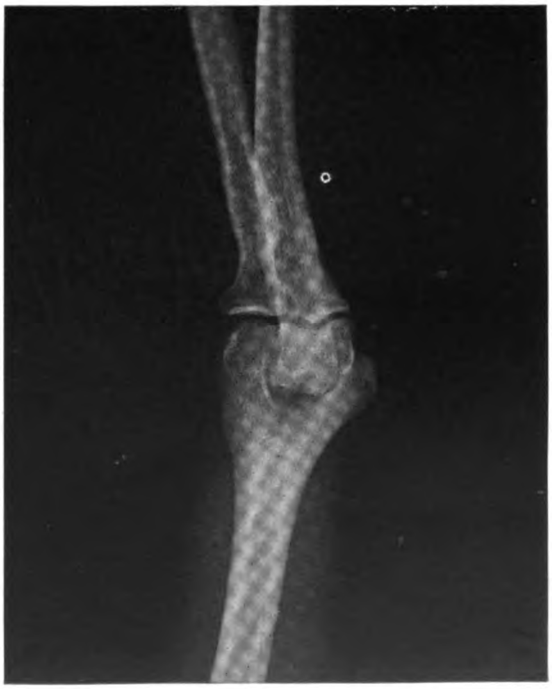


FIG. 249b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—7 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the elbow is in a dry cast add 8 kilovolts peak
- If the elbow is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  Without screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 56 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 46 kilovolts peak

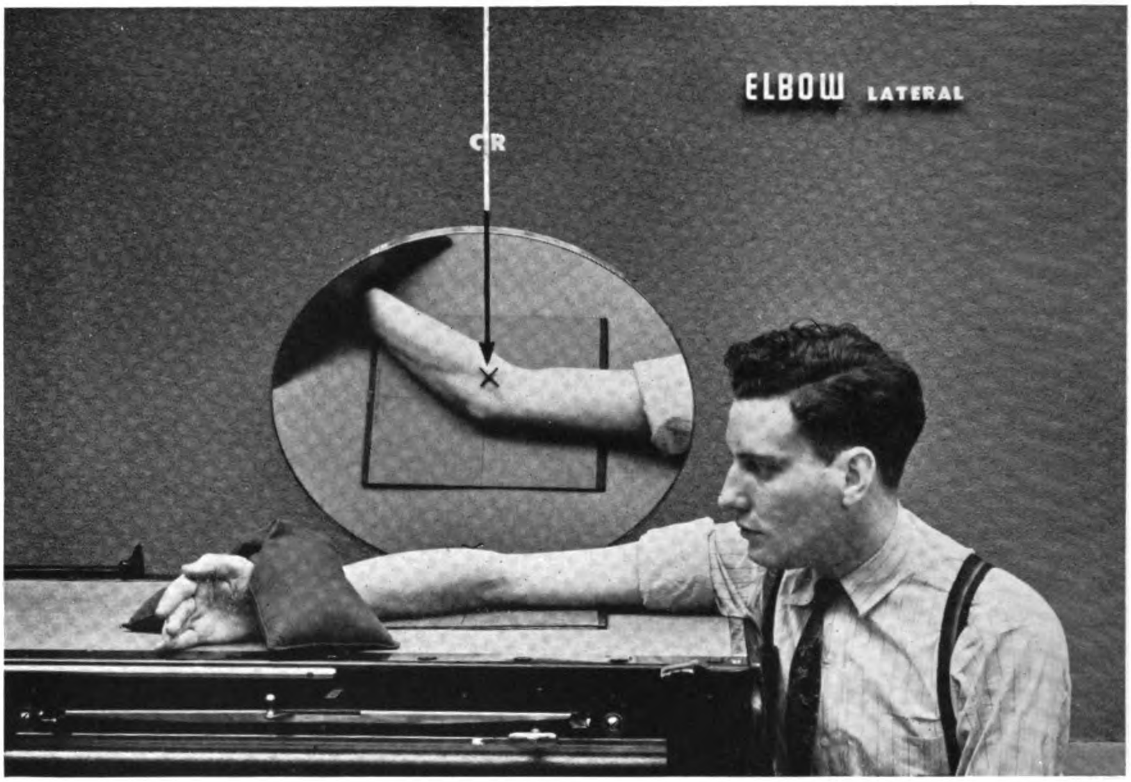


FIG. 250a

Elbow, Lateral

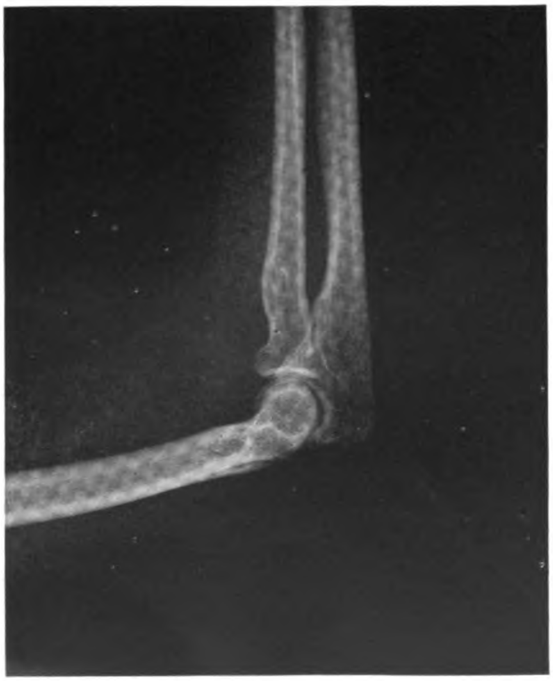


FIG. 250b

The arm and forearm rest on the film holder. When possible, the arm is flexed to approximately a 45-degree angle. The hand is turned sideways with thumb up. The medial epicondyle of the humerus is centered to the film. A sandbag is placed over the wrist for immobilization. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—8 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the elbow is in a dry cast add 8 kilovolts peak
- If the elbow is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 59 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 48 kilovolts peak

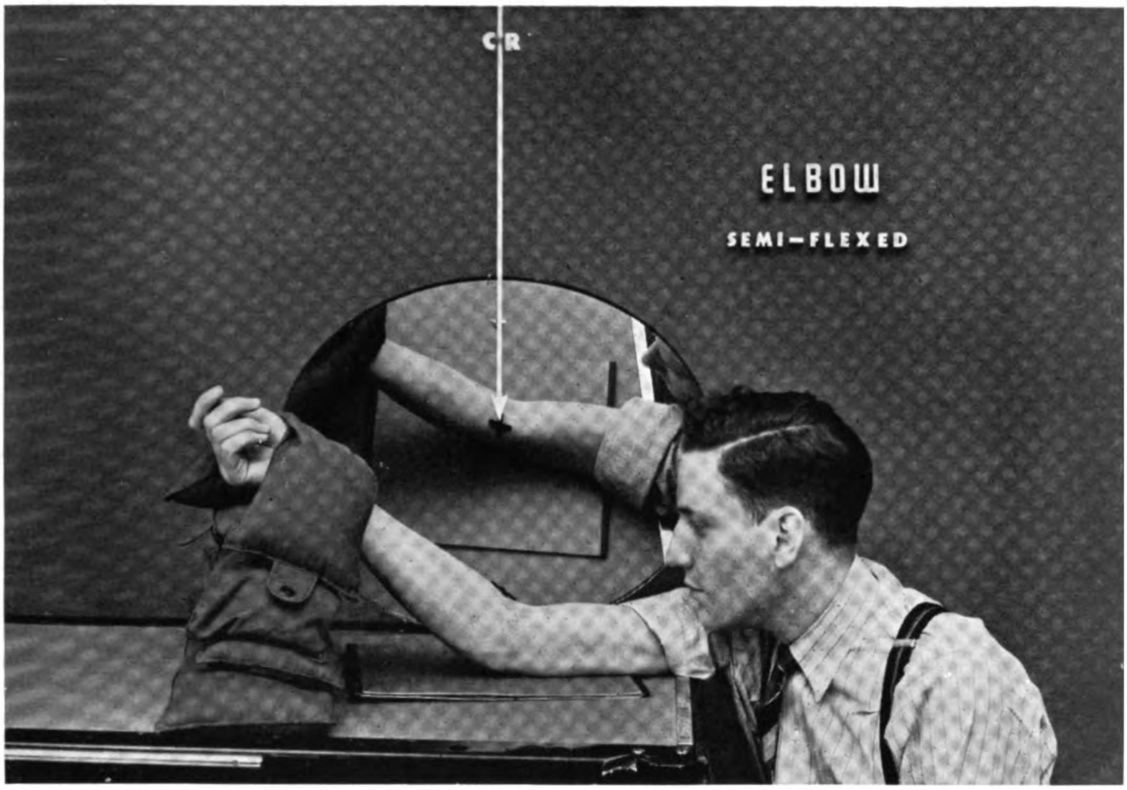


FIG. 251a

Elbow, Semi-Flexed

The arm is placed on the table with the forearm flexed and supported by sandbags. The amount of flexion will depend on the condition of the joint. The point midway between the epicondyles is placed over the center of the film holder. The central ray is directed to the center of the film.

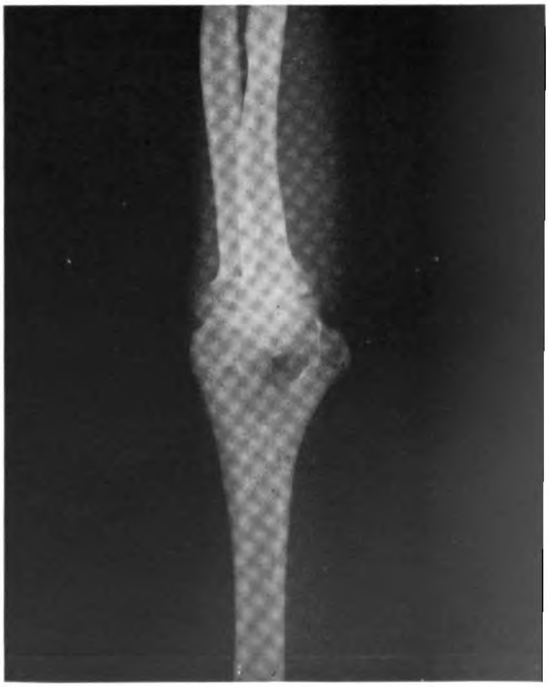


FIG. 251b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—7 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the elbow is in a dry cast add 8 kilovolts peak
- If the elbow is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 10-inch distance, 56 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 46 kilovolts peak

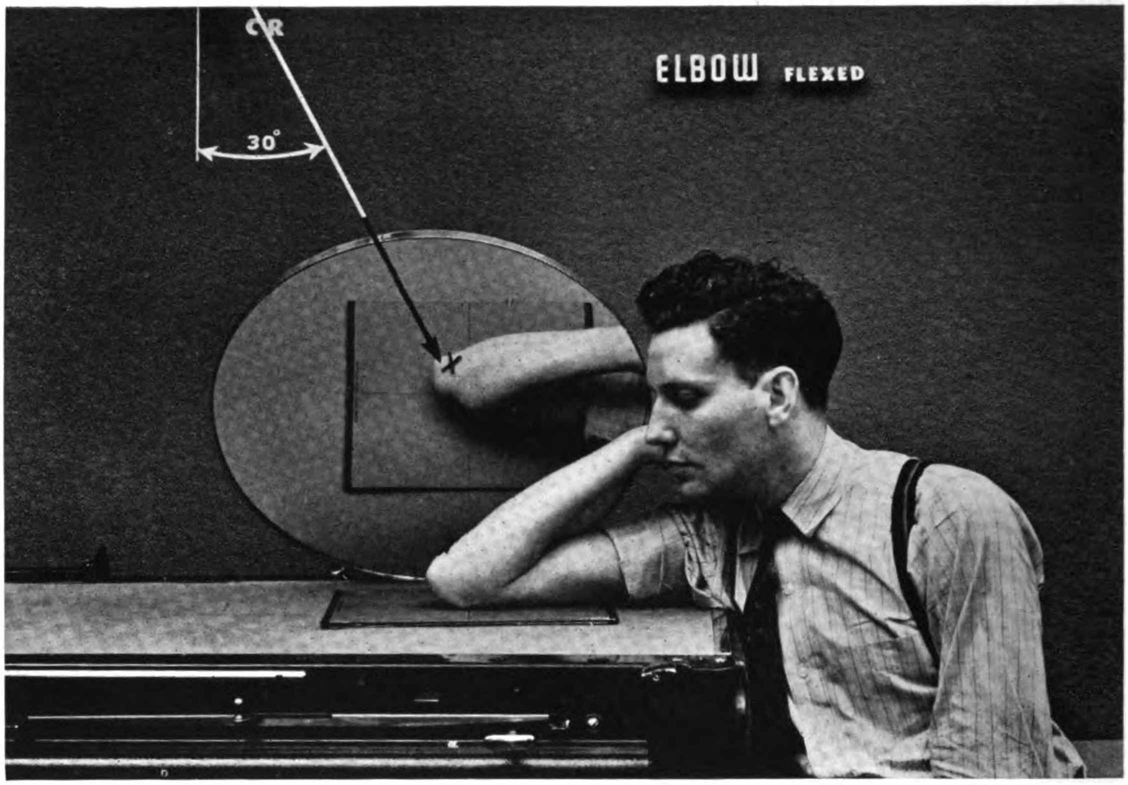


FIG. 252a

Elbow, Flexed

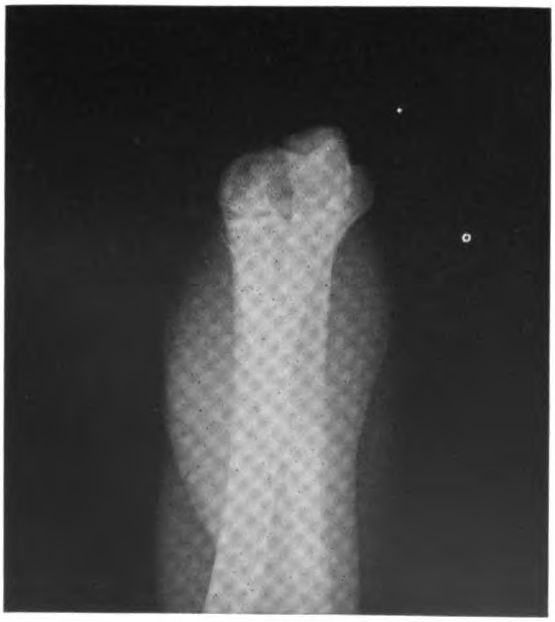


FIG. 252b

With the arm placed on the table, the forearm is flexed as completely as possible. The tube is tilted approximately 30 degrees toward the patient's head. The central ray passes through a point about two inches above the end of the olecranon process to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—9 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the elbow is in a dry cast add 8 kilovolts peak
- If the elbow is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 62 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 50 kilovolts peak

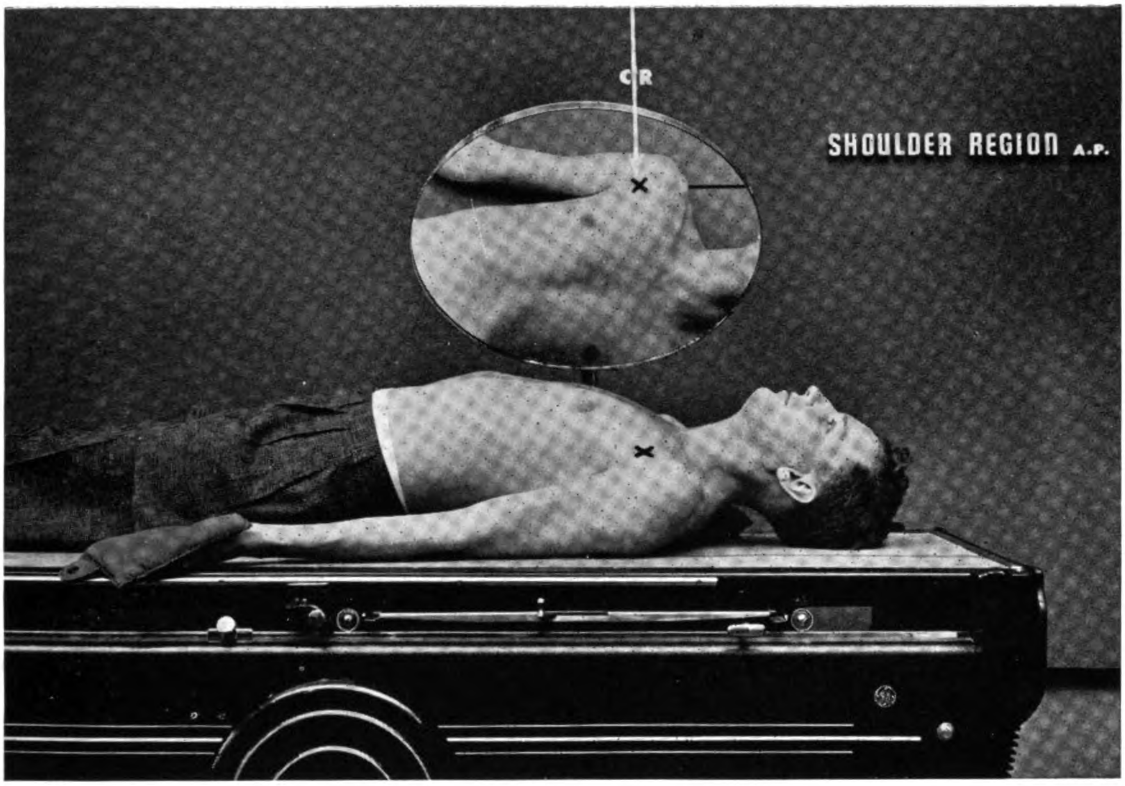


FIG. 253a

Shoulder, Antero-Posterior

Position I

With the patient in the supine position, one shoulder is elevated with sandbags to bring the shoulder that is to be radiographed directly on the film holder. The arm is abducted with the palmar surface of the hand upward. A point midway between the summit of the shoulder and the lower margin of the anterior axillary fold is centered to the film. The central ray is centered to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—14 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- If the shoulder is in a dry cast add 8 kilovolts peak
- If the shoulder is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 60 kilovolts peak
  With Parspeed screens, Potter-Bucky diaphragm, 25 milliampere-seconds, 40-inch distance, 56 kilovolts peak

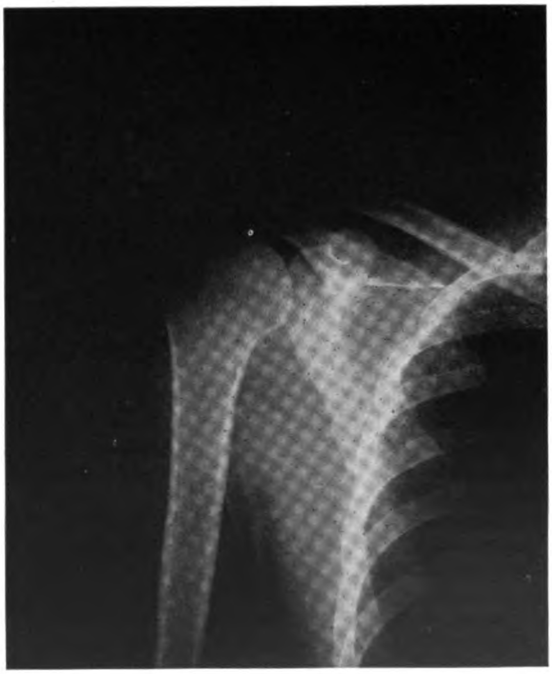


FIG. 253b

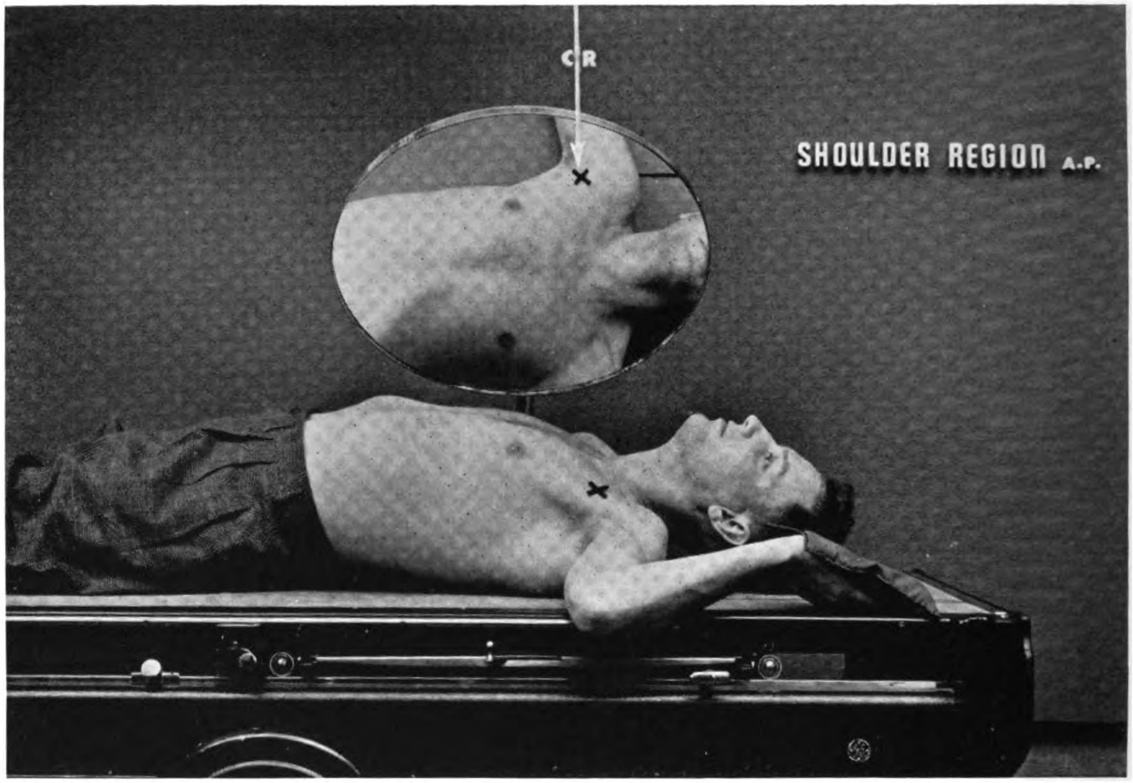


FIG. 254a

Shoulder, Antero-Posterior

Position II

The region, film, and tube are centered as in Position I. The arm is then placed at right angles to the median line, with the forearm flexed and immobilized. The exposure is made without recentering the tube or film holder. This position is primarily for radiography of the scapula.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—14 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- If the shoulder is in a dry cast add 8 kilovolts peak
- If the shoulder is in a wet cast add 12 kilvolts peak
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 60 kilovolts peak

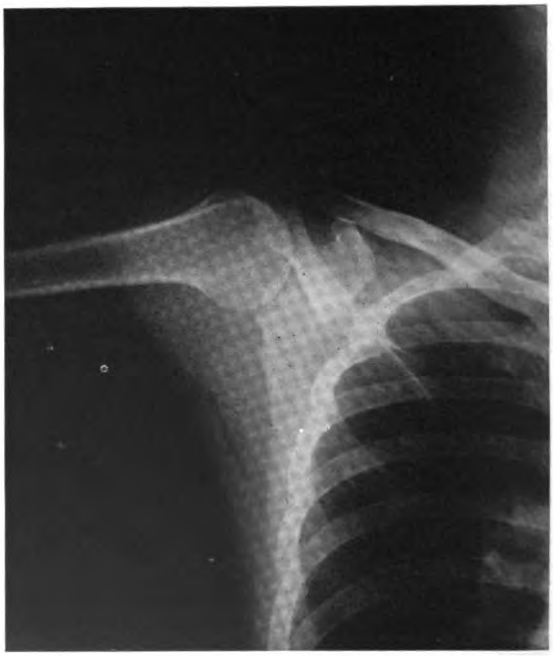


FIG. 254b

With Parspeed screens, with Potter-Bucky diaphragm. 25 milliampere-seconds, 40-inch distance, 56 kilovolts peak

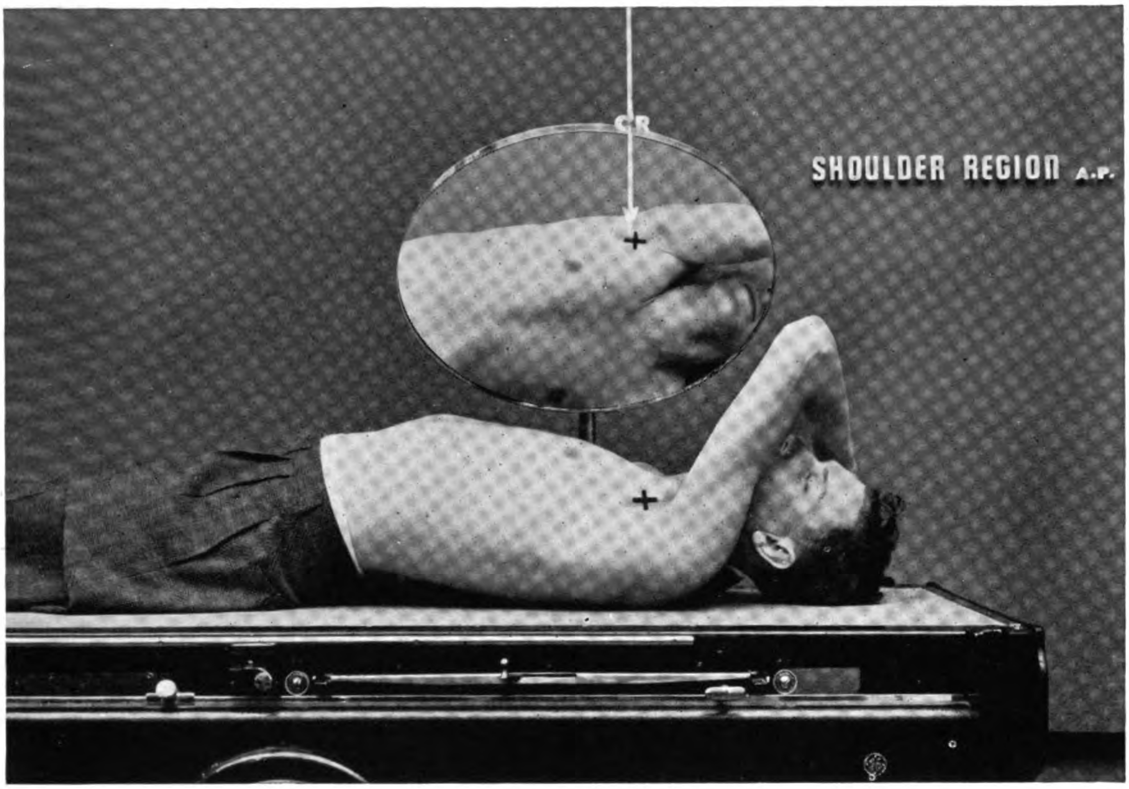


FIG. 255a

Shoulder, Antero-Posterior

Position III

The region, film, and tube are centered as in Position I. The arm is raised, flexed, and placed over the face so that the forearm rests on the forehead. The exposure is made without recentering tube or film holder. This position is primarily for radiography of the scapula.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—14 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- If the shoulder is in a dry cast add 8 kilovolts peak
- If the shoulder is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 60 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm,

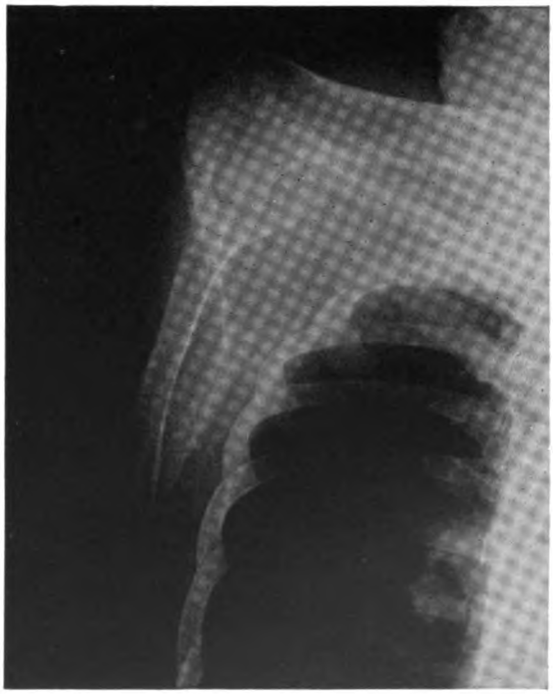


FIG. 255b

25 milliampere-seconds, 40-inch distance, 56 kilovolts peak

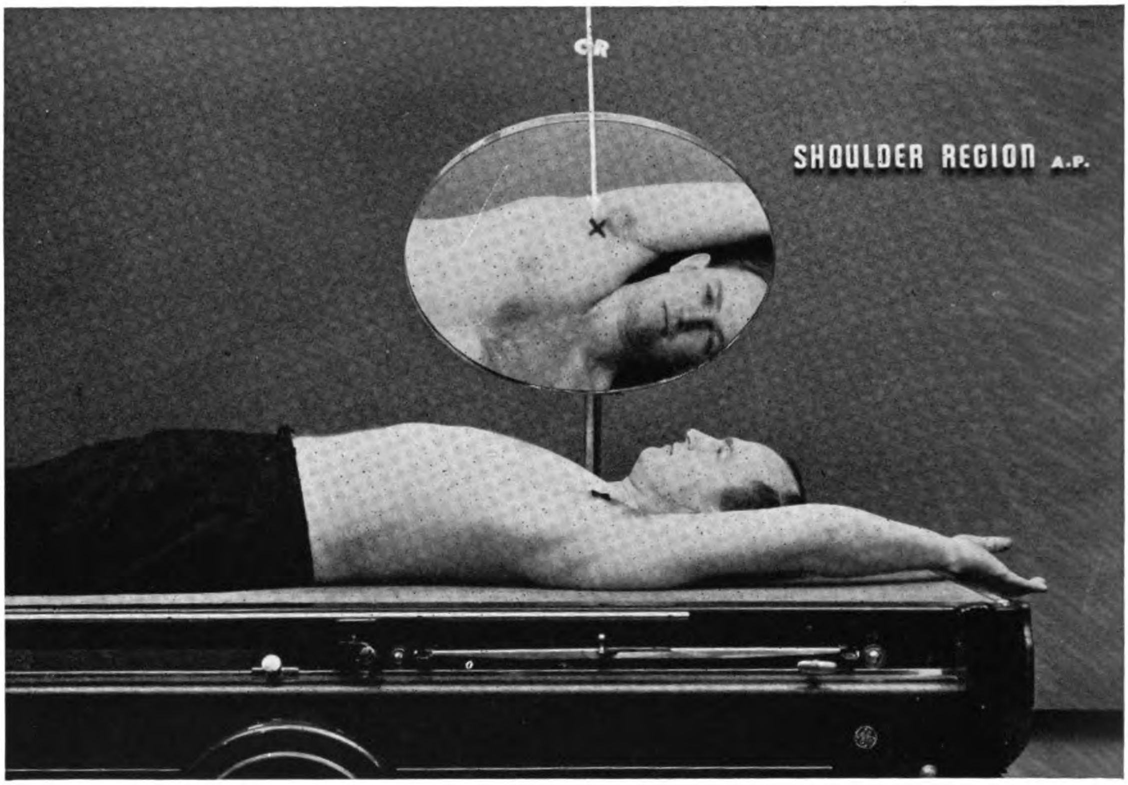


FIG. 256a

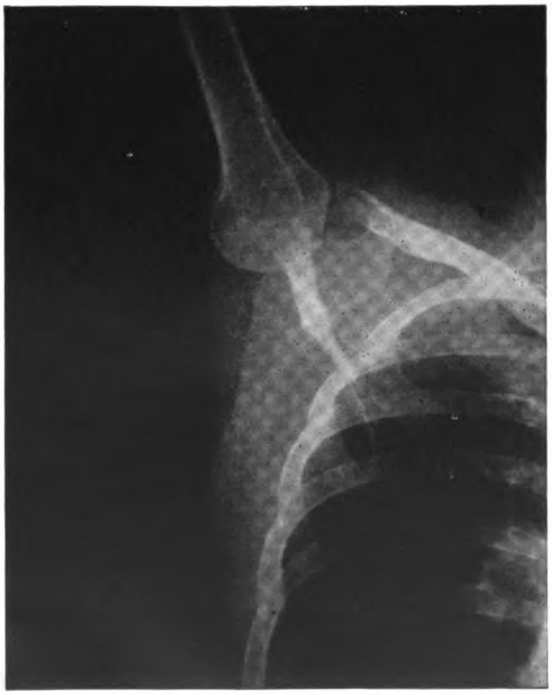


FIG. 256b

Shoulder, Antero-Posterior

Position IV

The region, film, and tube are centered as in Position I. The arm is raised until the hand and forearm are above the head. The exposure is made without recentering tube or film holder. This position is primarily for radiography of the scapula.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—14 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- If the shoulder is in a dry cast add 8 kilovolts peak
- If the shoulder is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 60 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragms, 25 milliampere-seconds, 40-inch distance, 56 kilovolts peak

Humerus, Lateral

The patient may be in the standing or sitting position, with the humerus to be examined placed against the upright table top or casette changer. The opposite arm is raised to avoid superimposition. The upper one-third of the humerus is centered to the center of the film. The tube is tilted approximately 15 degrees toward the patient's head, and the central ray is directed to the center of the film.

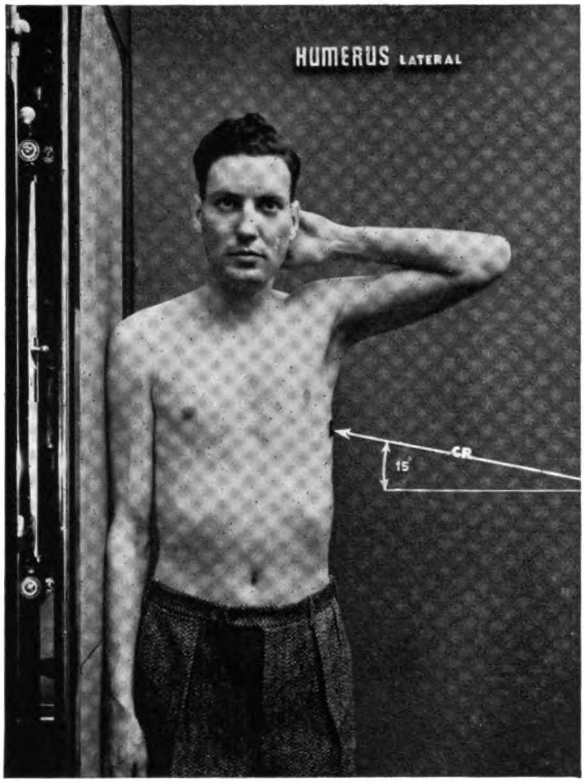


Fig. 257a

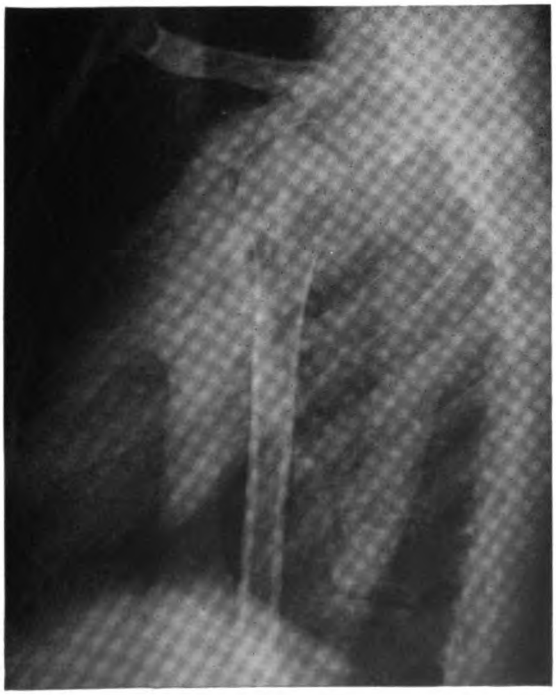


Fig. 257b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—30 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- If the shoulder is in a dry cast add 8 kilovolts peak
- If the shoulder is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**

  With Parspeed screens, without Potter-Bucky diaphragm, 10 milliampere-seconds, 30-inch distance, 74 kilovolts peak

  With Parspeed screens, with Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 68 kilovolts peak

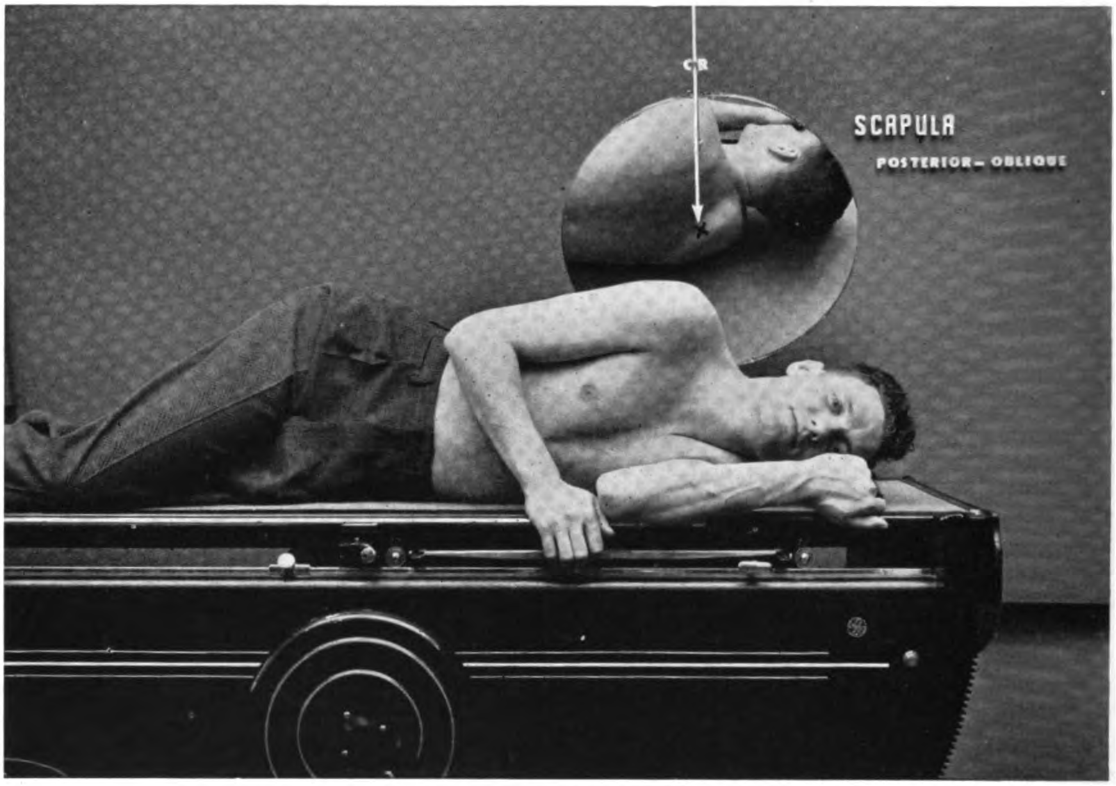


FIG. 258a

Scapula, Postero-Oblique

The patient is placed in the lateral position with the affected shoulder against the table. By rotating the patient forward, the scapula is separated from the thorax. The midpoint of the vertebral border of the scapula is placed over the center of the film. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—14 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- If the shoulder is in a dry cast add 8 kilovolts peak
- If the shoulder is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 60 kilovolts peak

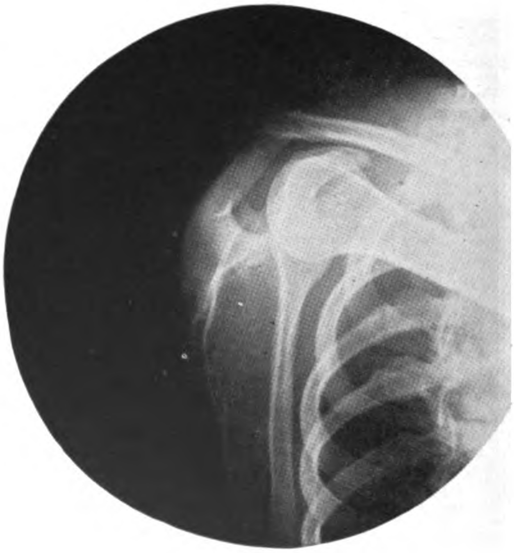


FIG. 258b

With Parspeed screens, with Potter-Bucky diaphragms, 25 milliampere-seconds, 40-inch distance, 56 kilovolts peak

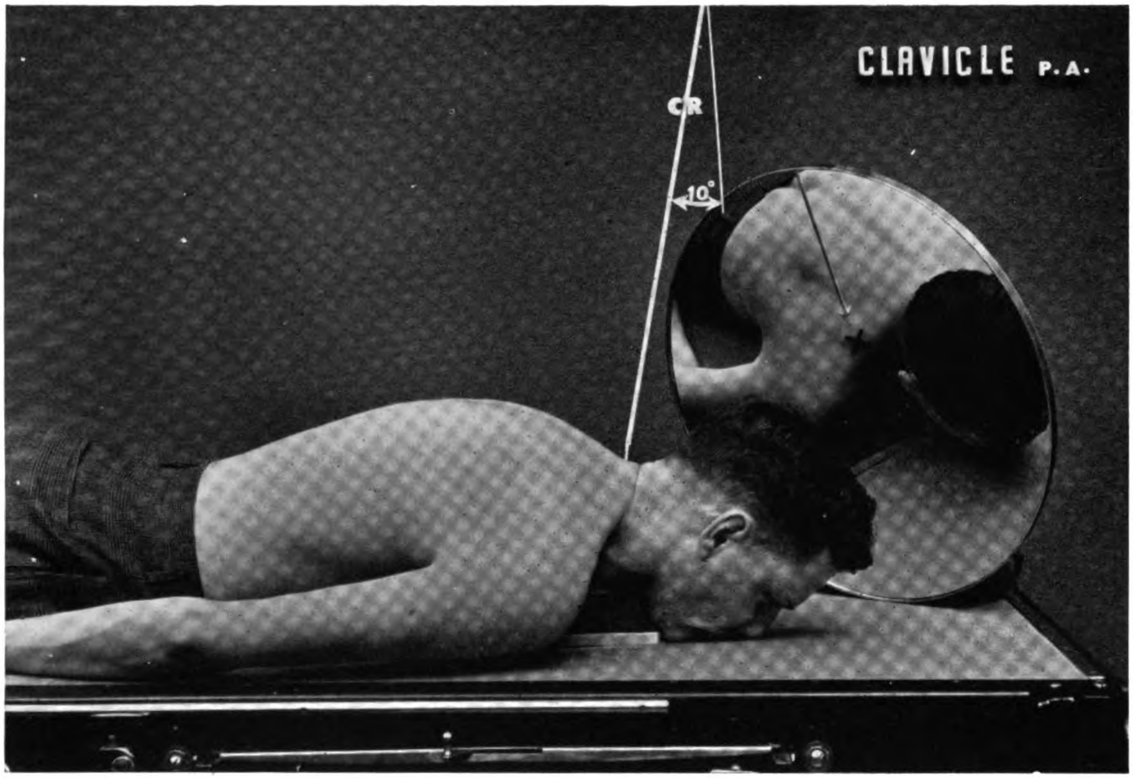


FIG. 259a

Clavicle, Postero-Anterior

The patient is placed in the prone position with the arms at the sides of the body. The midpoint of the clavicle is located over the center of the film. The tube is angled 10 degrees toward the patient's feet with the central ray directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 60 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 50 milliampere-seconds, 40-inch distance, 56 kilovolts peak

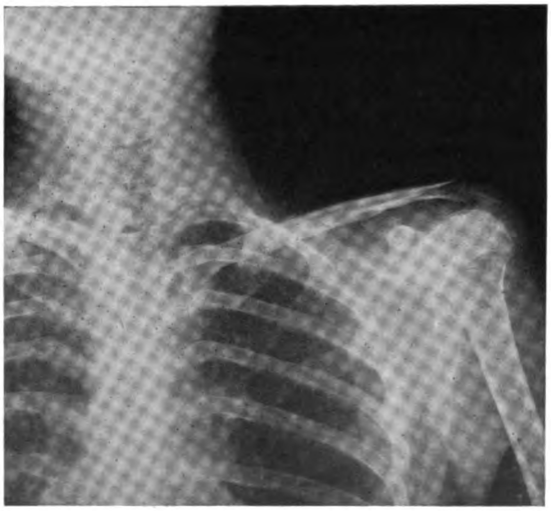


FIG. 259b

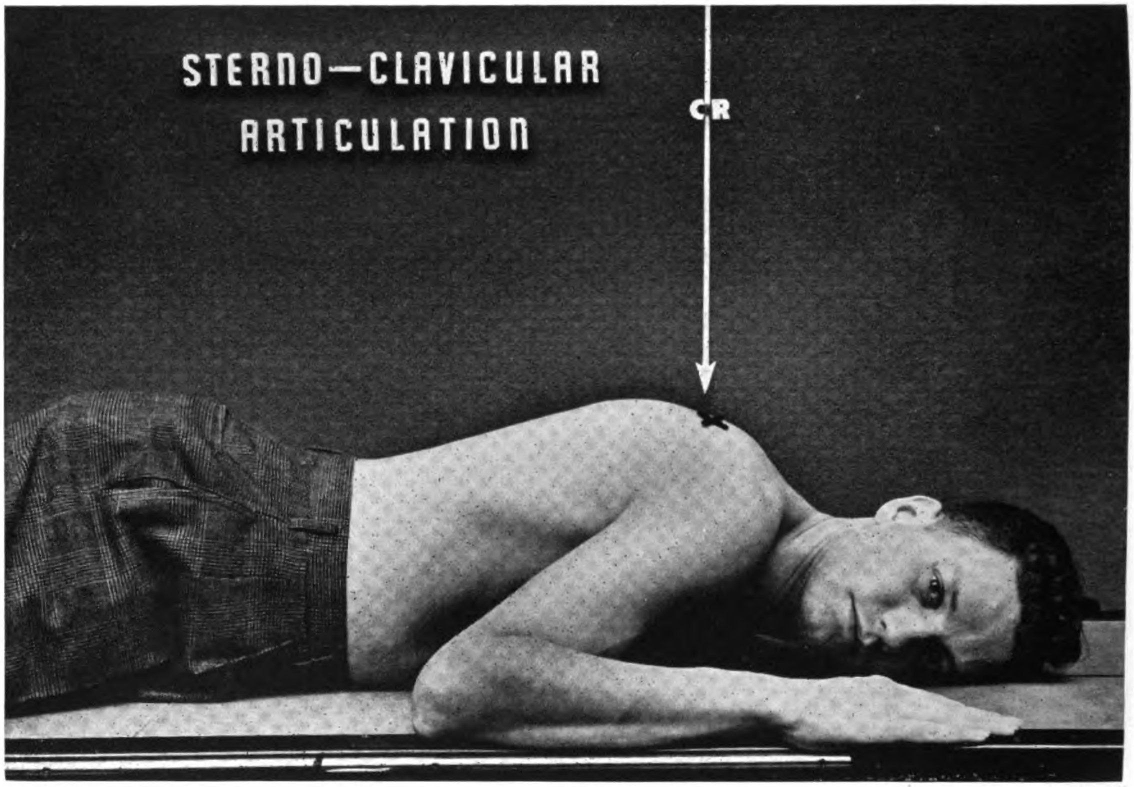


FIG. 260a

Sterno-Clavicular Articulation

The patient is placed in the prone position and rotated slightly so the dorsal spine will not be superimposed on the articulation being radiographed. If the right articulation is to be radiographed, the right arm and leg are flexed, which will enable the patient to maintain this position. The articulation is placed over the center of the film, and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—25 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- A close focal-film distance is used in order to blur out the intervening structures, in this case the posterior ribs and heart shadow
- **Suggested starting technic:**

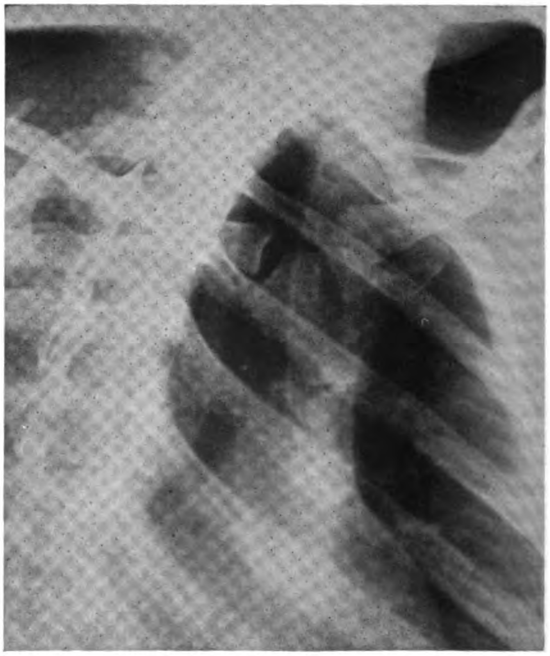


FIG. 260b

With Parspeed screens, with Potter-Bucky diaphragm, 25 milliampere-seconds, 30-inch distance, 56 kilovolts peak

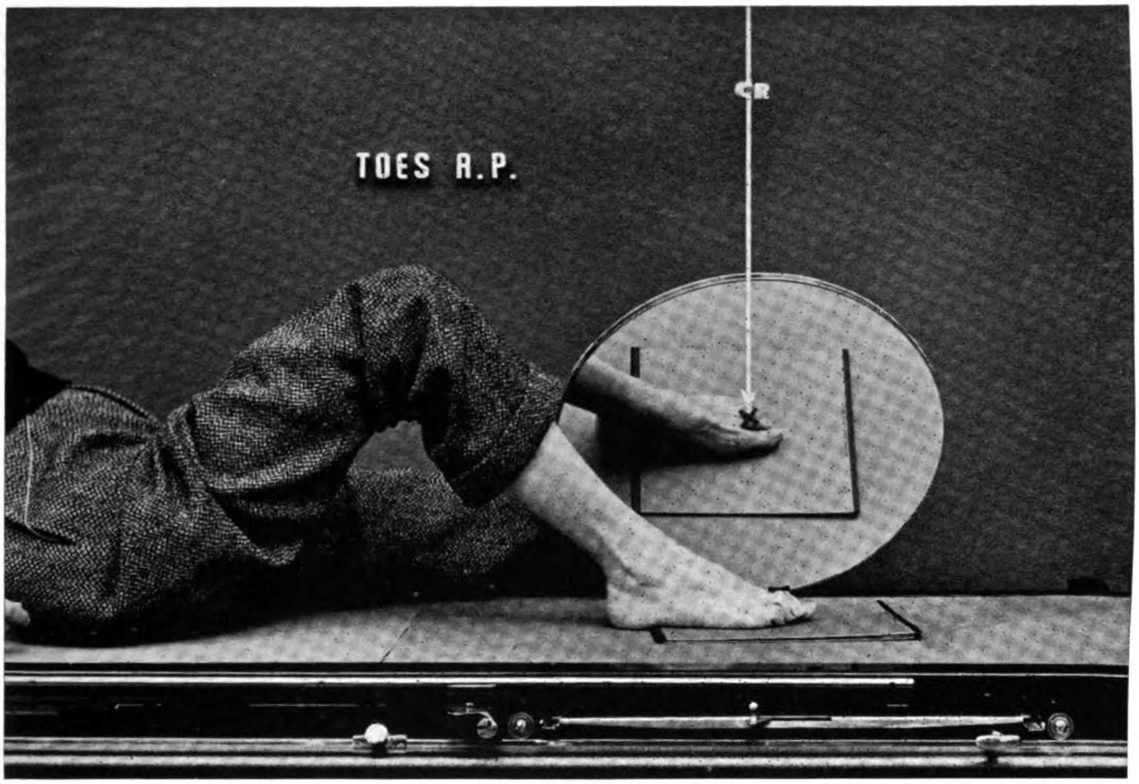


FIG. 261a

Toes, Antero-Posterior

The patient may sit or lie on the table. The knee is elevated to form an acute angle. The distal end of the third metatarsal bone is placed over the center of the film. The central ray is directed to the center of the film.

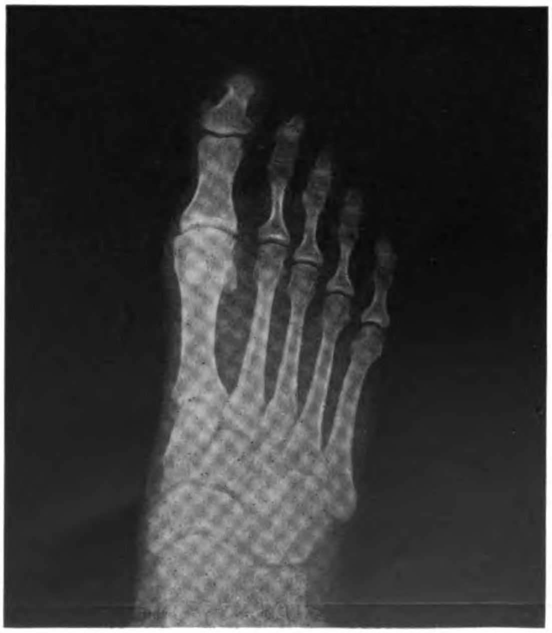


FIG. 261b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—4 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the part is in a dry cast add 5 kilovolts peak
- If the part is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**

Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 44 kilovolts peak

With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 38 kilovolts peak

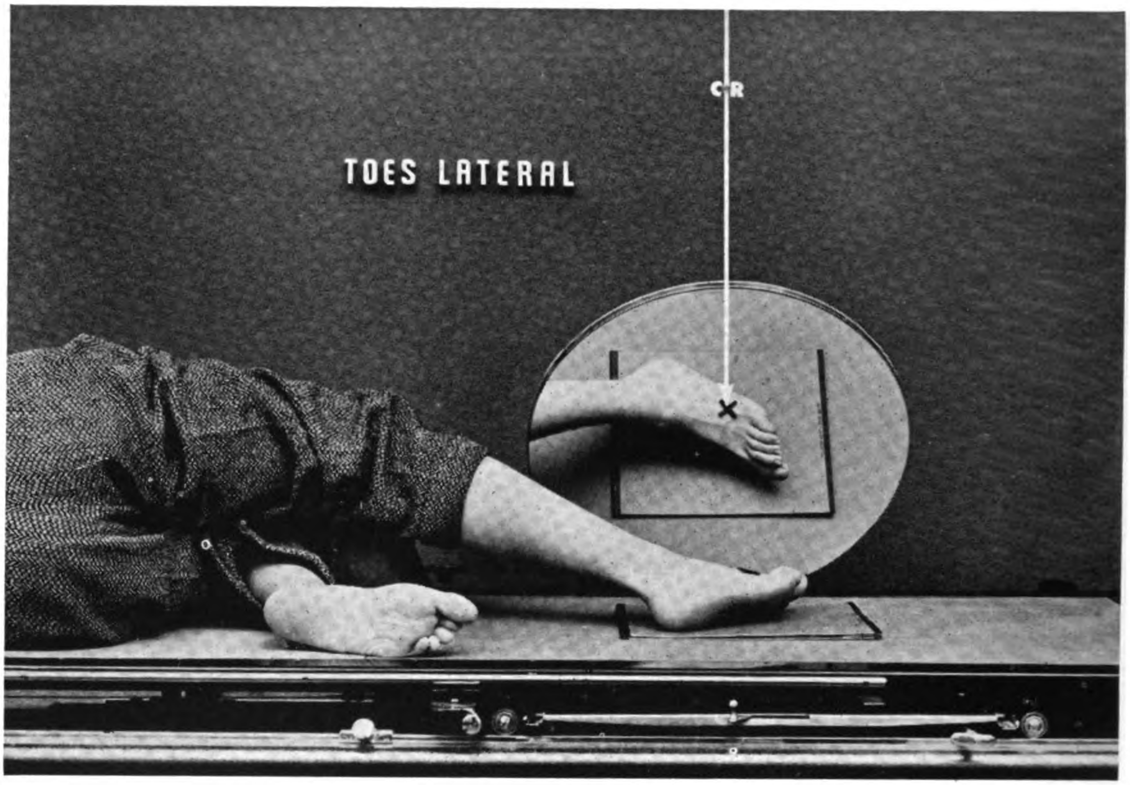


FIG. 262a

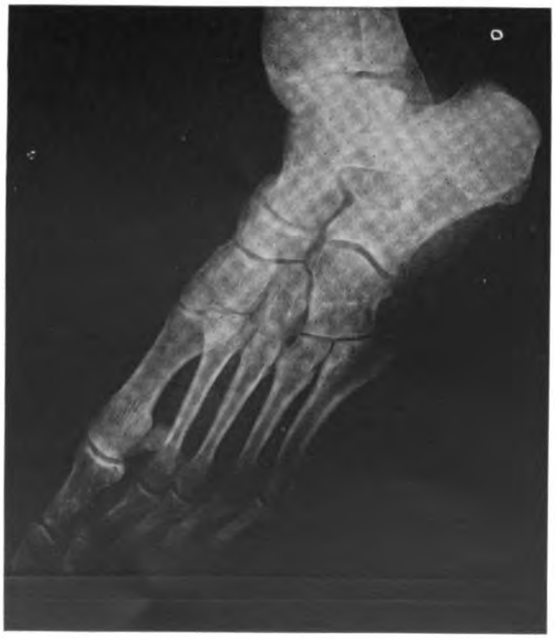


FIG. 262b

Toes, Lateral

The patient is placed in the lateral position with the knee elevated and supported by sandbags. The distal end of the fourth metatarsal is centered to the center of the film holder, and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—8 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the toes are in a dry cast add 5 kilovolts peak
- If the toes are in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**

  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 59 kilovolts peak

  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 50 kilovolts peak

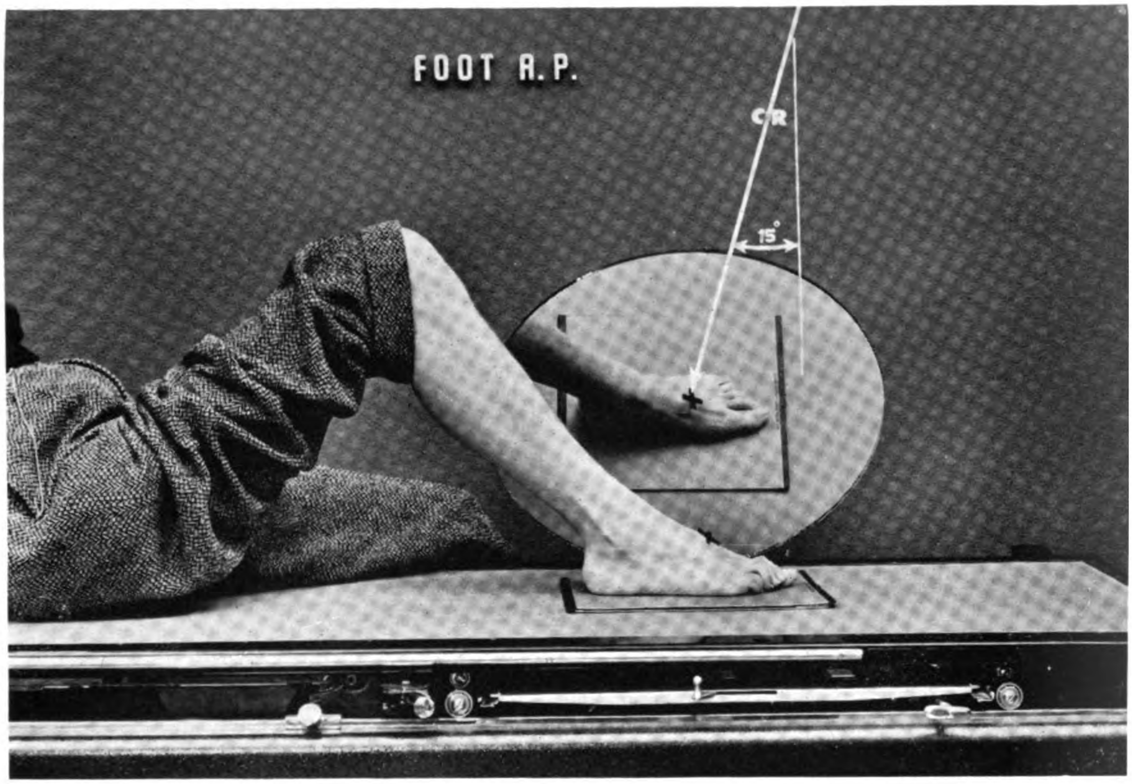


Fig. 263a

Foot, Antero-Posterior

The patient may lie or sit on the table. With the knee flexed at an acute angle, the plantar surface of the foot rests on the film holder. The proximal end of the second metatarsal is centered to the film holder. The tube is tilted 15 degrees toward the patient's head, and the central ray is directed to the center of the film.

In some cases, to obtain adequate separation of the metatarsal bones, it may be necessary to use two tube tilts: one, as already described; and a second, a tilt of 15 degrees toward the medial side of the foot. The central ray is again directed to the center of the film.

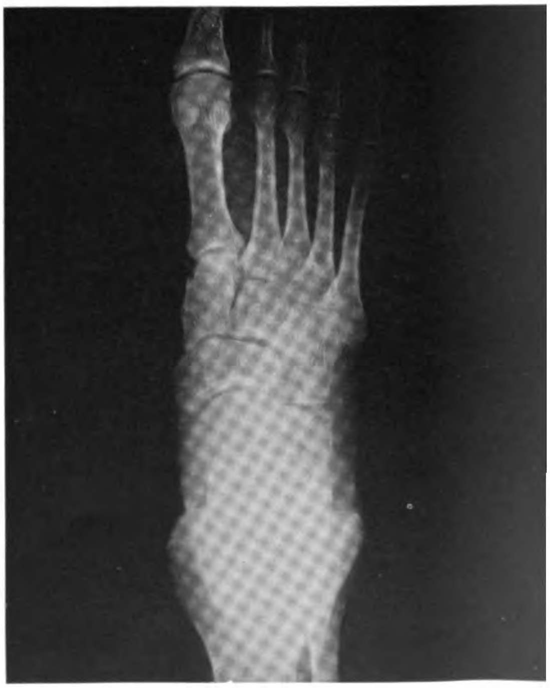


Fig. 263b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part—6 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the foot is in a dry cast add 5 kilovolts peak
- If the foot is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 50 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 42 kilovolts peak

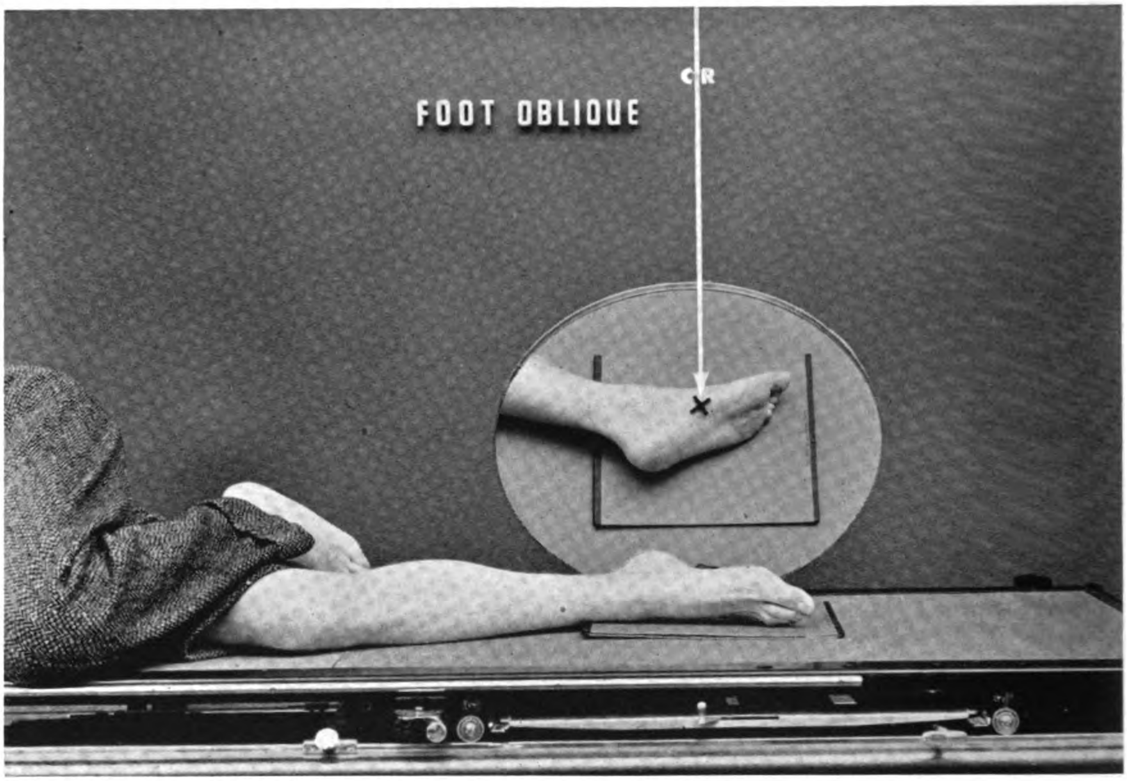


FIG. 264a

Foot, Oblique

The patient is placed in the lateral position. By elevating the heel, the dorsal surface of the foot is brought in contact with the film holder. The opposite leg is crossed over. A point midway between the heel and the great toe is placed over the center of the film. The central ray is directed to the center of the film.

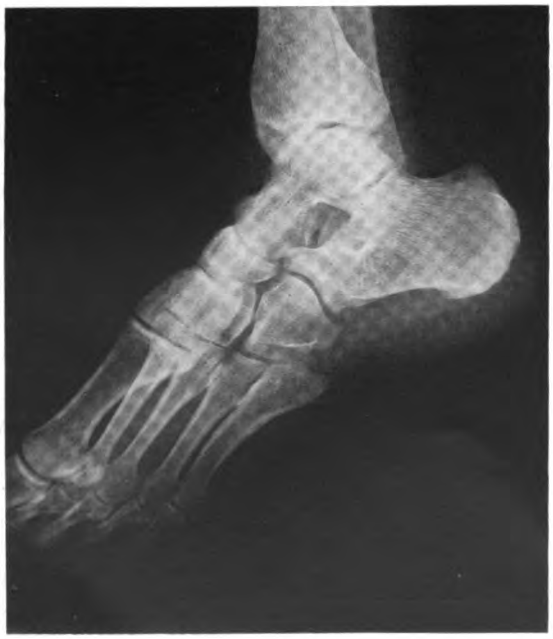


FIG. 264b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—7 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the foot is in a dry cast add 5 kilovolts peak
- If the foot is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 53 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 44 kilovolts peak

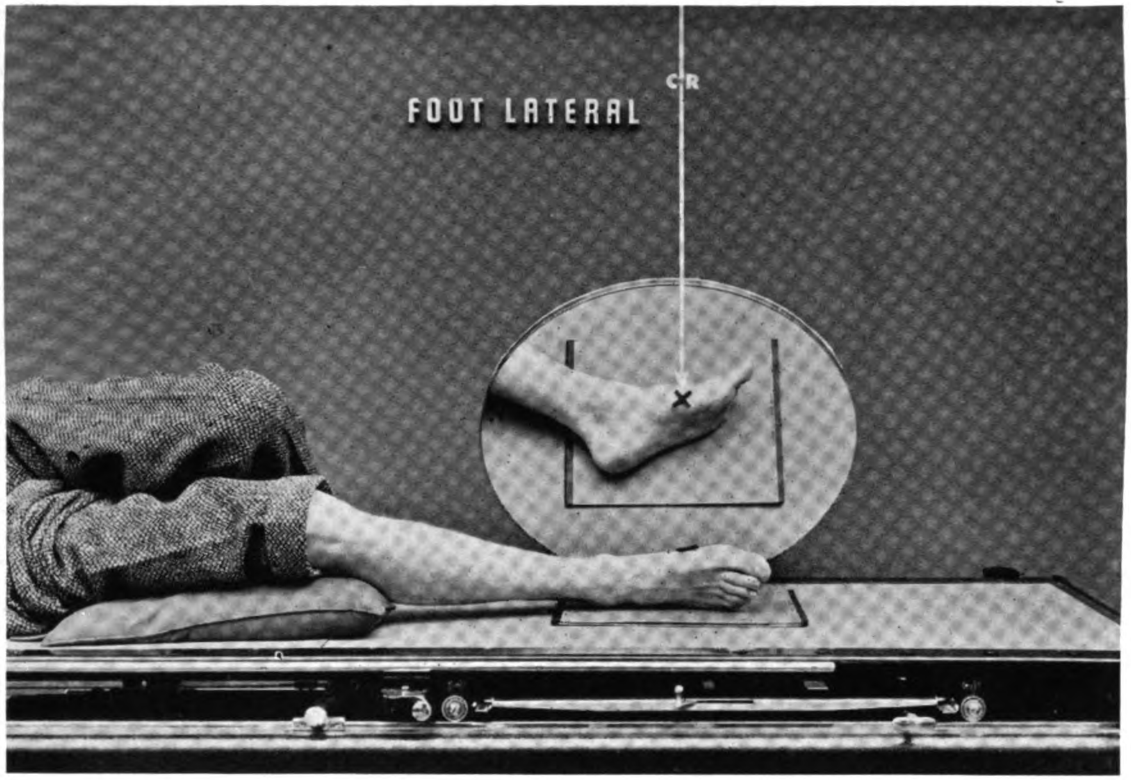


FIG. 265a

Foot, Lateral

The patient is placed in the lateral position with the leg to be radiographed slightly flexed and supported by sandbags at the knee. A point approximately one-third the distance from the end of the great toe to the heel is centered to the film holder. The central ray is directed to the center of the film.

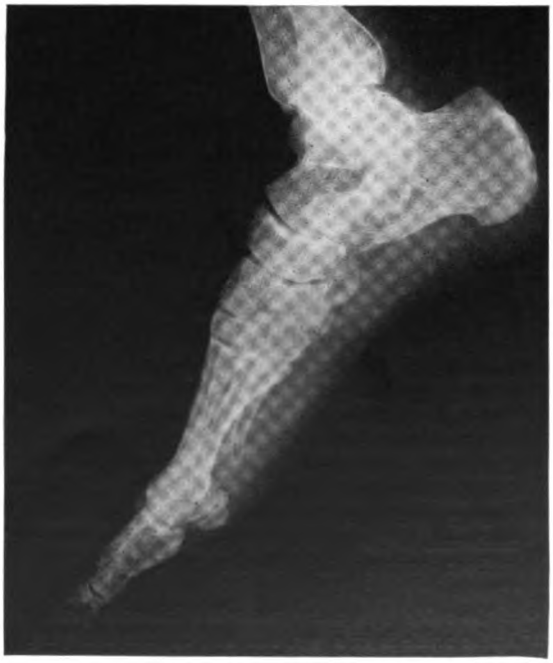


FIG. 265b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—8 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak without screens; 8 kilovolts peak with Parspeed screens
- If the foot is in a dry cast add 5 kilovolts peak
- If the foot is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 56 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 46 kilovolts peak

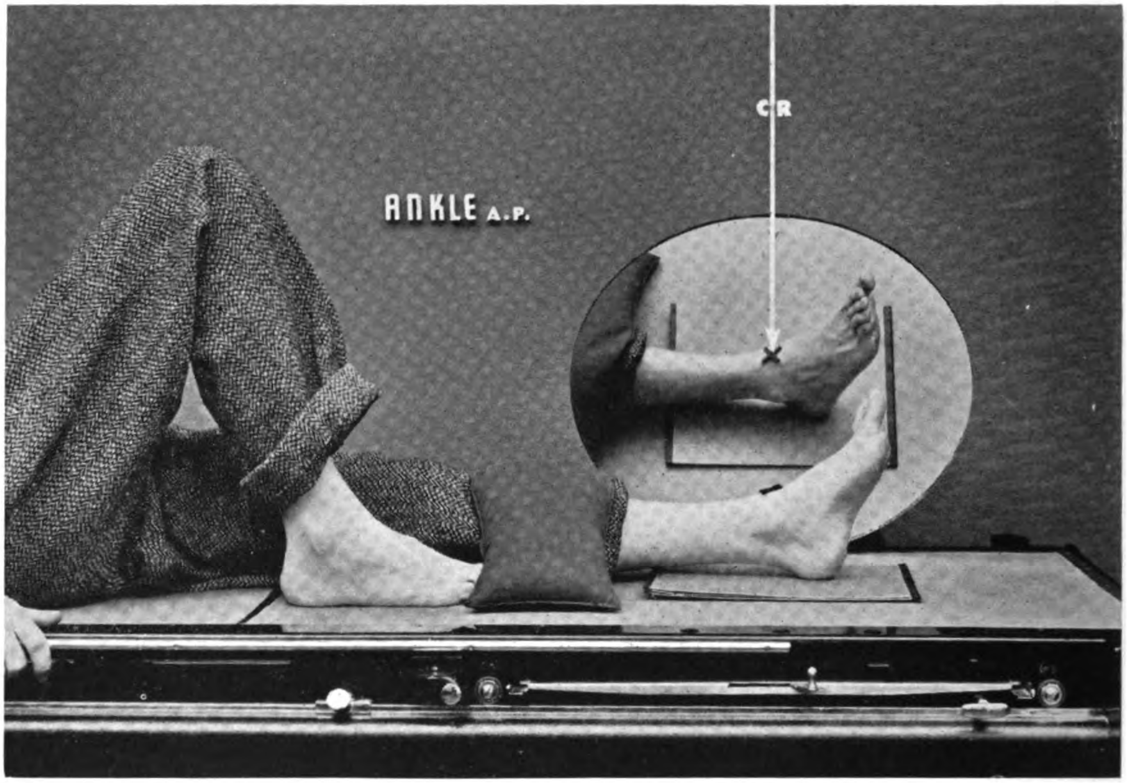


FIG. 266a

Ankle, Antero-Posterior

The patient is placed in the supine position with the heel resting on the film holder. A sandbag is placed over the knee. The lower tip of the internal malleolus is centered over the crossline of the film holder when viewed from the side of the table. The point midway between the malleoli is centered to the centerline of the film holder from the end of the table, and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—9 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the ankle is in a dry cast add 6 kilovolts peak
- If the ankle is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 62 kilovolts peak

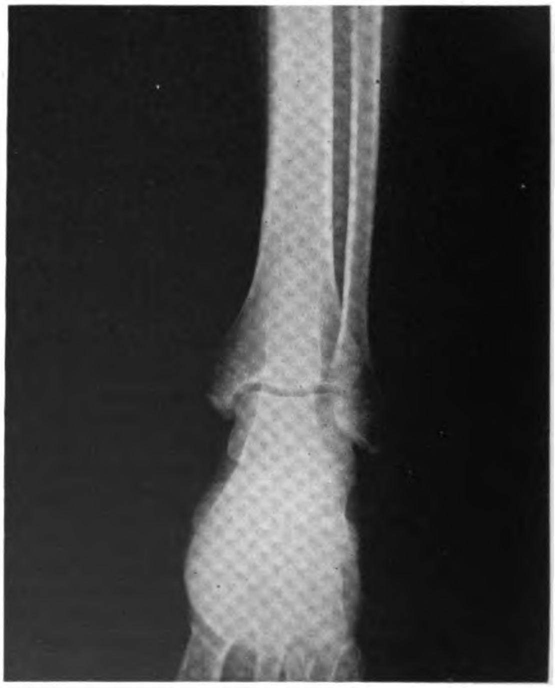


FIG. 266b

With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 50 kilovolts peak

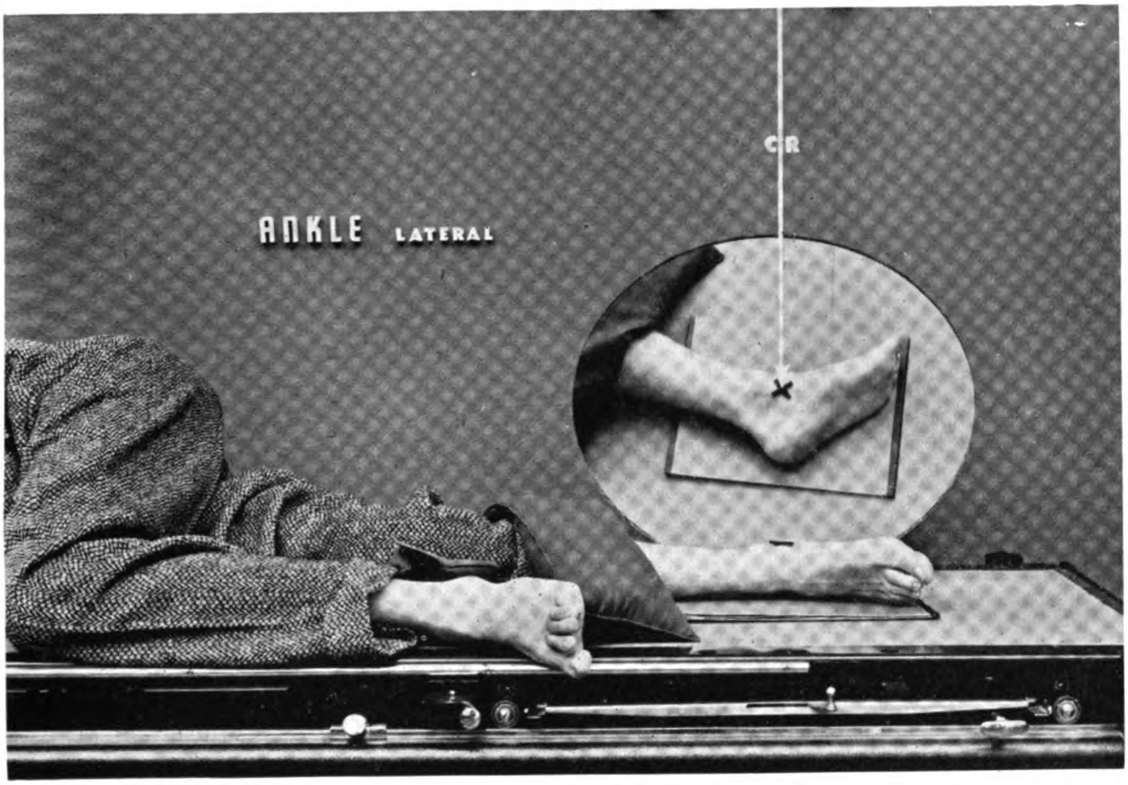


FIG. 267a

Ankle, Lateral

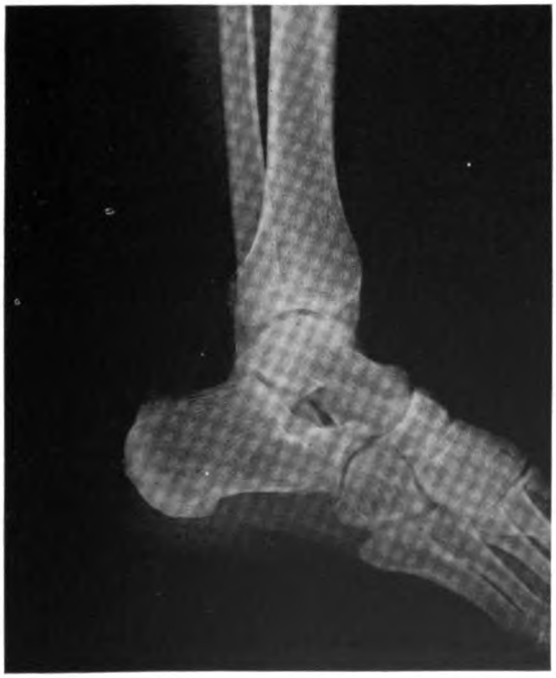


FIG. 267b

The patient is placed in the lateral position. The ankle is placed on the film or cassette with the external malleolus against the film. The opposite leg is crossed over. The lower tip of the internal malleolus is centered to the film holder, and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—7 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the ankle is in a dry cast add 6 kilovolts peak
- If the ankle is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 53 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 44 kilovolts peak

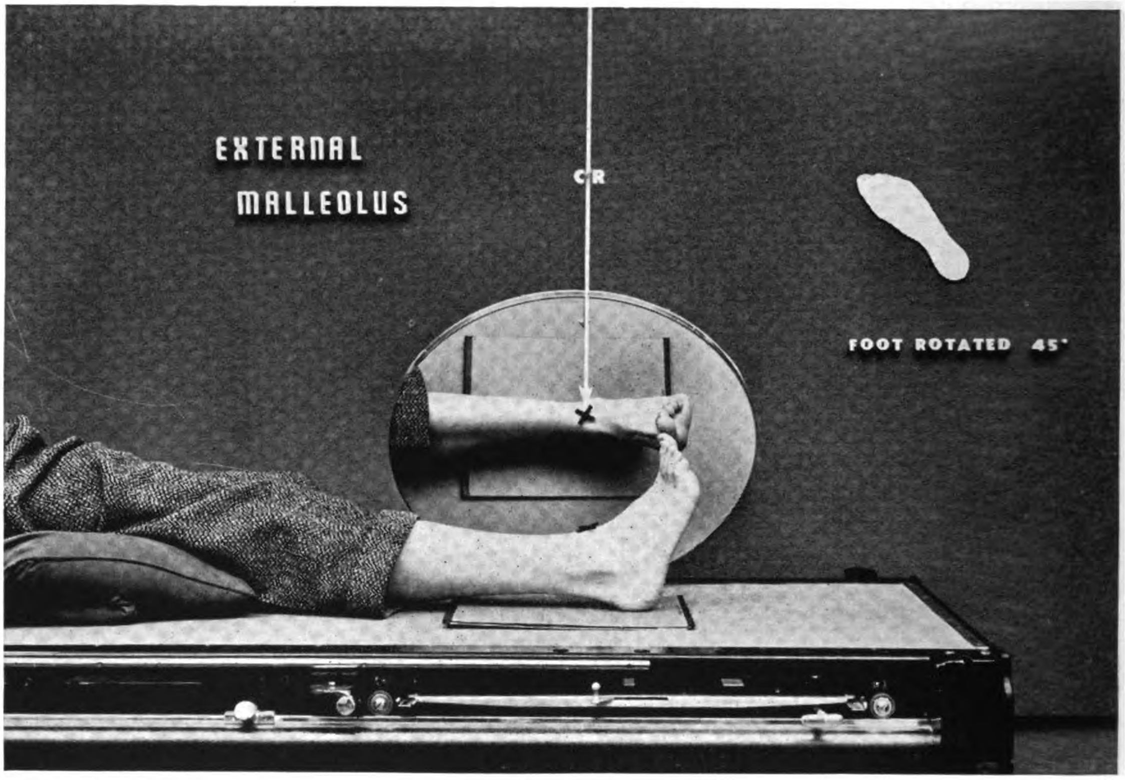


FIG. 268a

External Malleolus

The patient is placed in the supine position. The leg is rotated 45 degrees and maintained in position by placing sandbags under the thigh and knee. The lower tip of the internal malleolus is centered to the crossline of the film holder. The central ray is directed to the midpoint between the malleoli which is placed over the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—9 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the ankle is in a dry cast add 6 kilovolts peak
- If the ankle is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 62 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 50 kilovolts peak

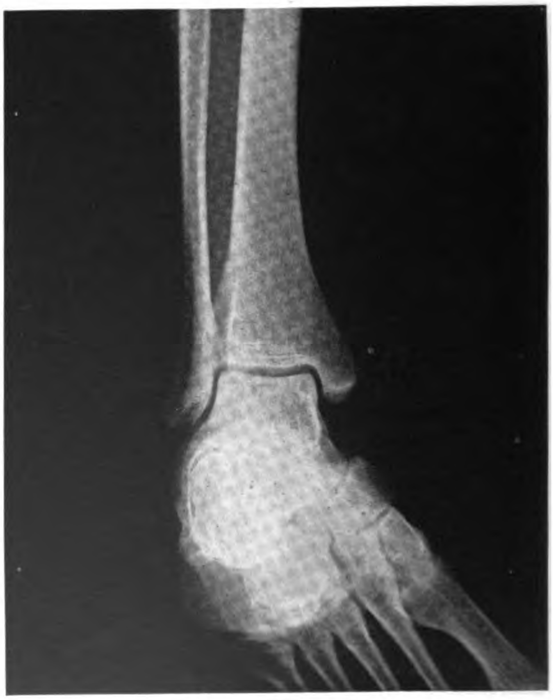


FIG. 268b

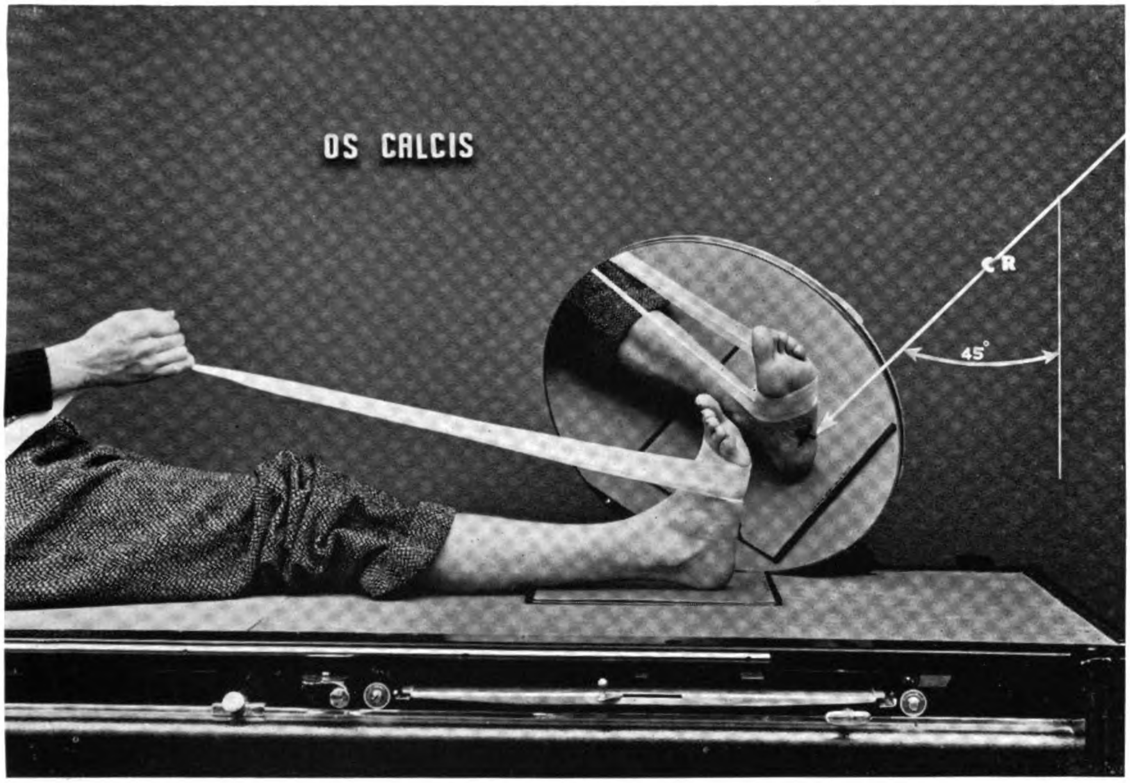


FIG. 269a

Os Calcis, Infero-Superior

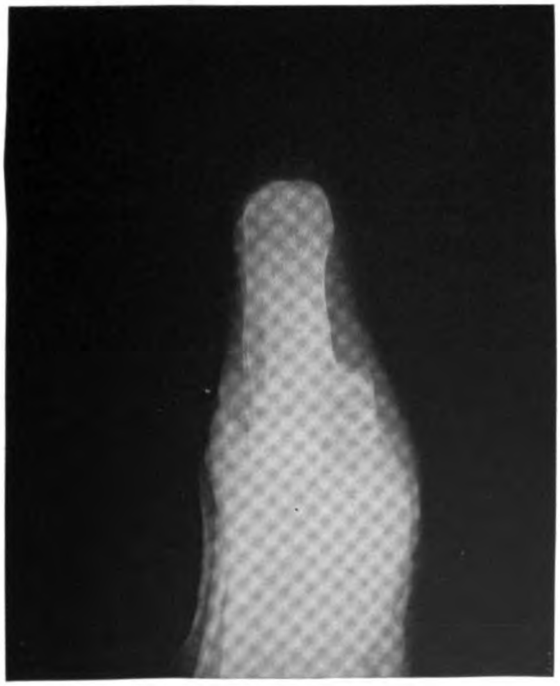


FIG. 269b

The patient is placed in the supine position. Tension is applied by a bandage wrapped around the foot, which also immobilizes the part. The tube is angled 45 degrees toward the patient's head, and the central ray is directed through a point just above the heel to the center of the film holder.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—7 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the ankle is in a dry cast add 6 kilovolts peak
- If the ankle is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 53 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 44 kilovolts peak

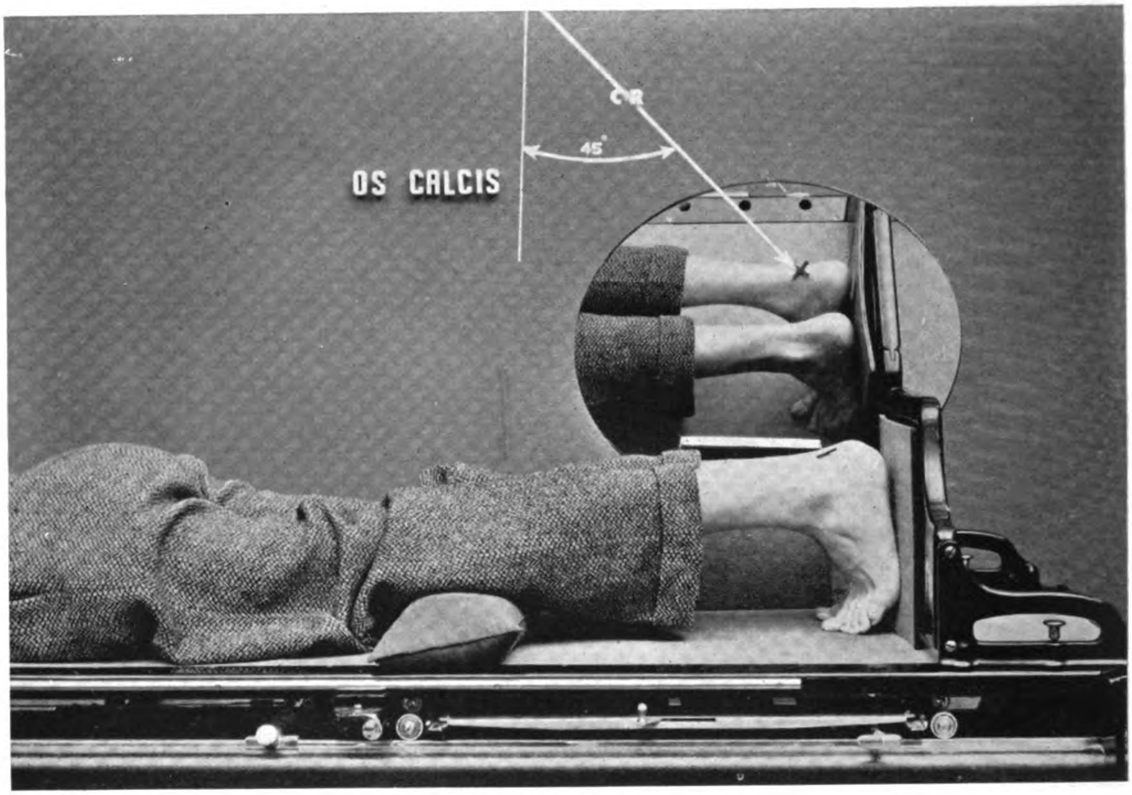


FIG. 270a

Os Calcis, Supero-Inferior

The patient is placed in the prone position with a sandbag under the knee. The film holder is supported by the table footrest or by sandbags. The tube is angled 45 degrees toward the feet. This angle may vary with different patients as it is determined by the degree of flexion of the foot. The central ray is directed through a point midway between the ankle and the back of the heel. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—7 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak without screens; 12 kilovolts peak with Parspeed screens
- If the ankle is in a dry cast add 6 kilovolts peak
- If the ankle is in a wet cast add 10 kilovolts peak
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 53 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 44 kilovolts peak

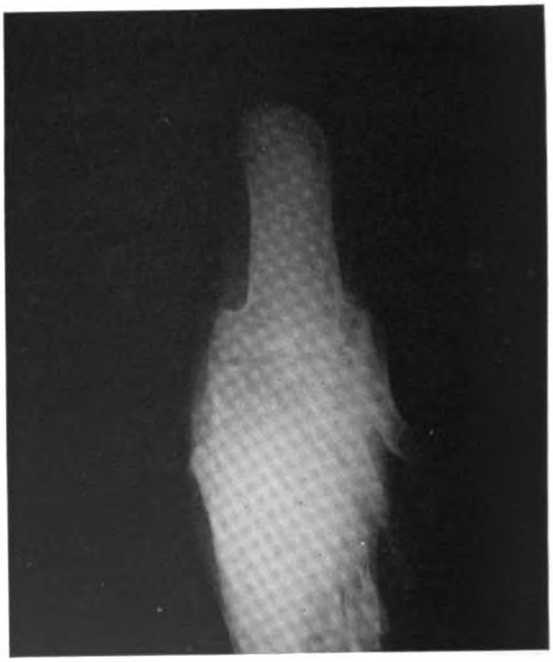


FIG. 270b

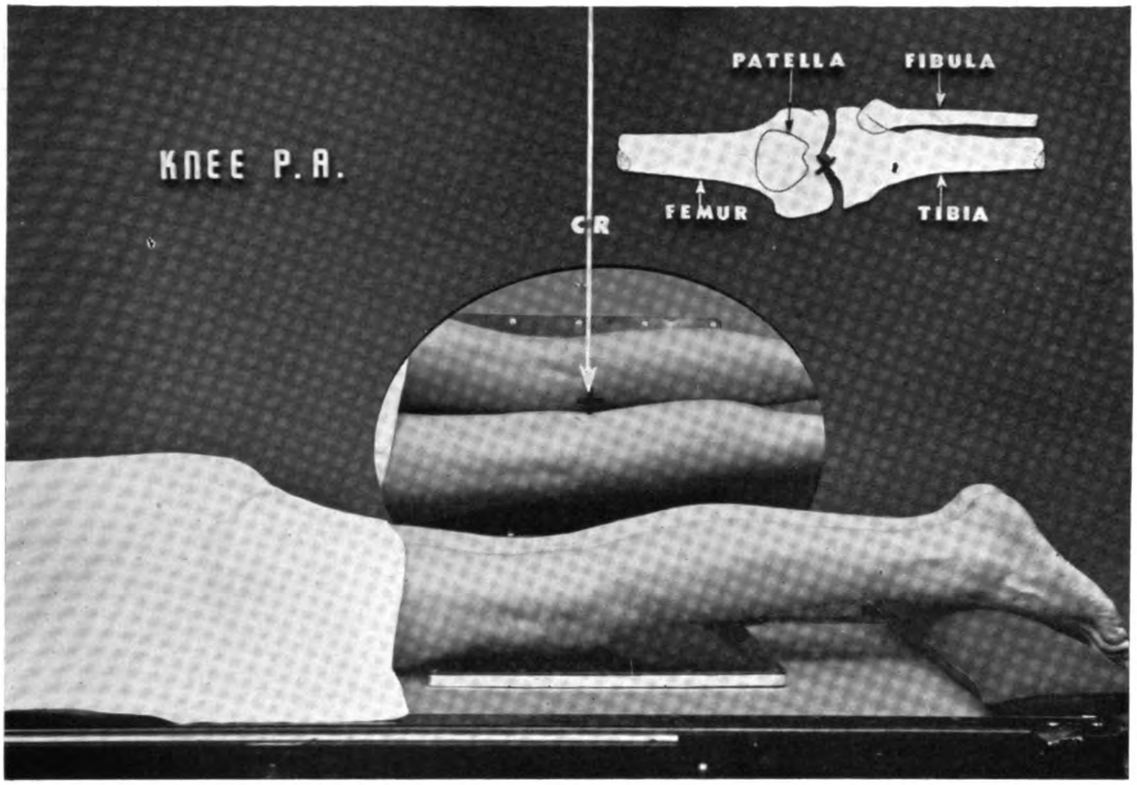


FIG. 271a

Knee, Postero-Anterior

The patient is placed in the prone position. Sandbags are placed under the feet to support the toes. The lower margin of the patella is placed over the crossline of the film with the midpoint between the condyles of the femur over the centerline. The central ray is directed to the center of the film.

For the antero-posterior view, the patient is placed on the table in the supine position. The relationship of part to film remains the same as for the postero-anterior view.

For a comparative radiograph, both knees are taken on one film with one exposure.

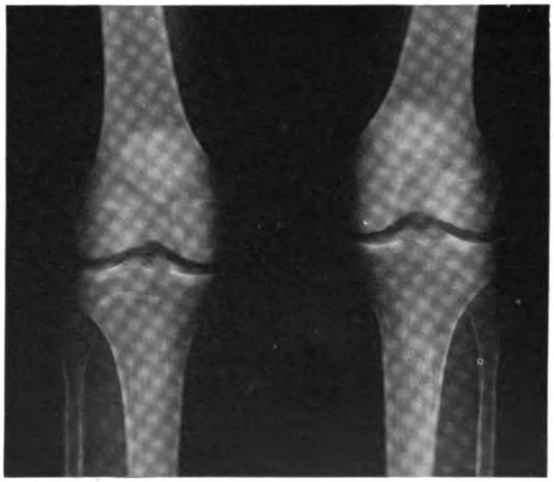


FIG. 271b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—12 centimeters
- If the knee is in a dry cast add 8 kilovolts peak
- If the knee is in a wet cast add 12 kilovolts peak

- **Suggested starting technic:**

  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 56 kilovolts peak

  With Parspeed screens, with Potter-Bucky diaphragm, 25 milliampere-seconds, 40-inch distance, 50 kilovolts peak

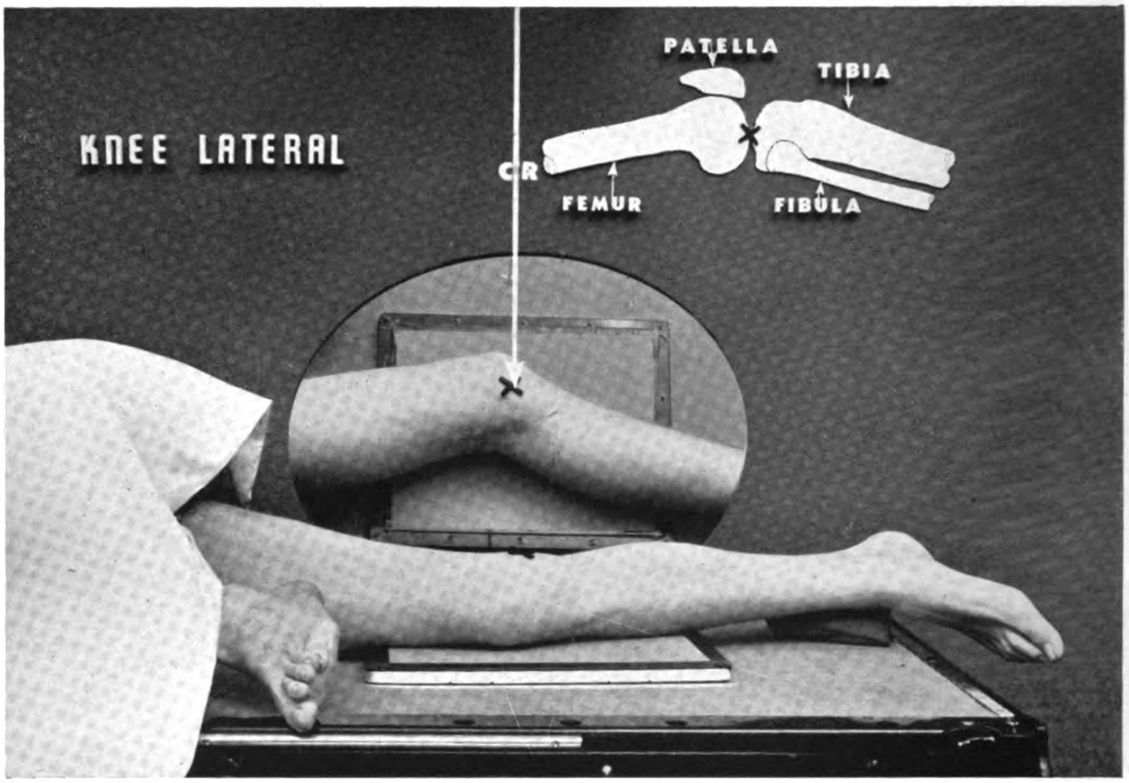


Fig. 272a

Knee, Lateral

The patient is placed on the table in the lateral position with the affected knee resting on the film holder. When viewed from the side of the table, the lower margin of the patella is centered to the crossline of the film holder, and when viewed from the end of the table, the midpoint of the knee region is centered to the center of the film. With some patients it may be necessary to tilt the tube from 5 degrees to 10 degrees toward the patient's head in order to obtain separation of the joint space. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—10 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- If the knee is in a dry cast add 8 kilovolts peak
- If the knee is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 52 kilovolts peak

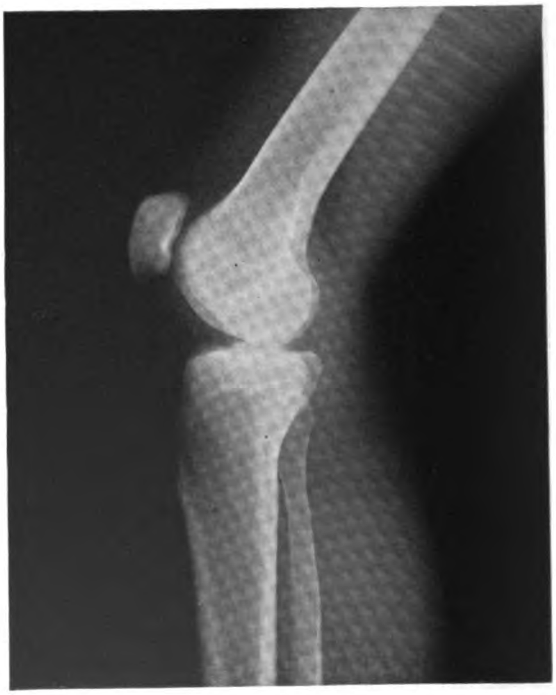


Fig. 272b

With Parspeed screens, with Potter-Bucky diaphragm, 25 milliampere-seconds, 40-inch distance, 46 kilovolts peak

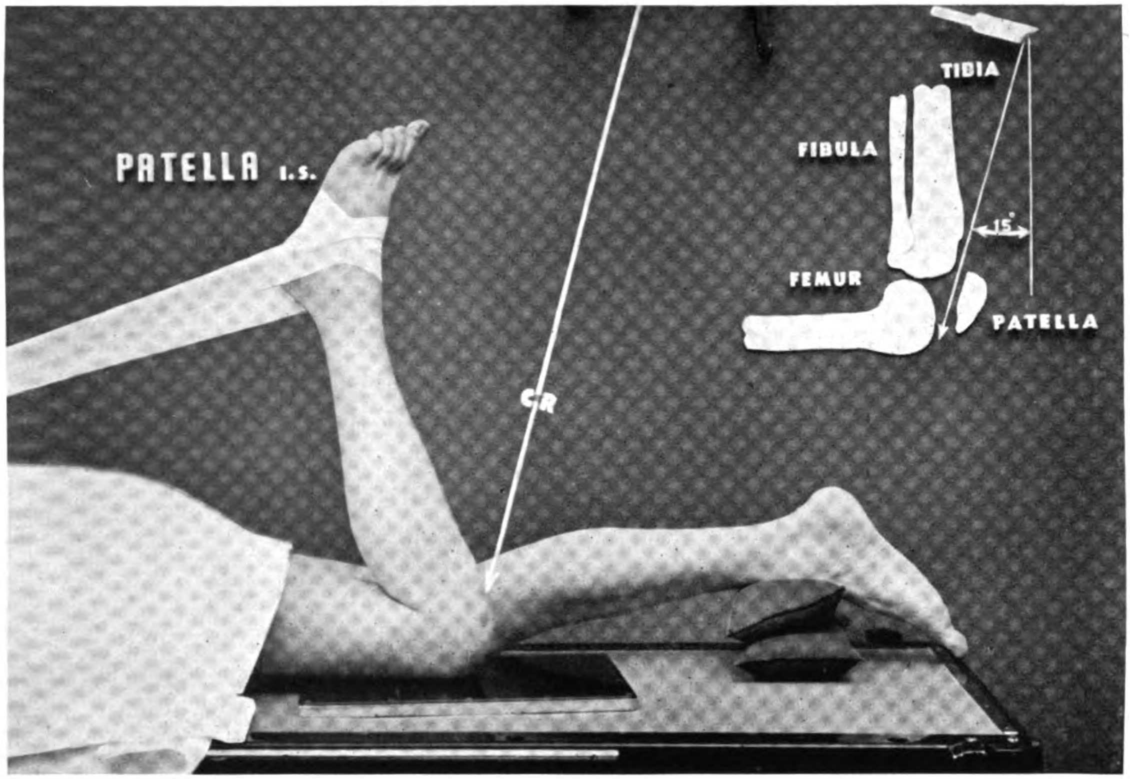


FIG. 273a

Patella, Infero-Superior

The patient is placed in the prone position. The knee is flexed. Tension is applied on a bandage or tape wrapped around the foot as shown in the illustration. The tube is angled approximately 15 degrees toward the patient's head. The angulation depends on how much the knee can be flexed. The central ray passes between the patella and the head of the femur. The film is centered to the central ray.

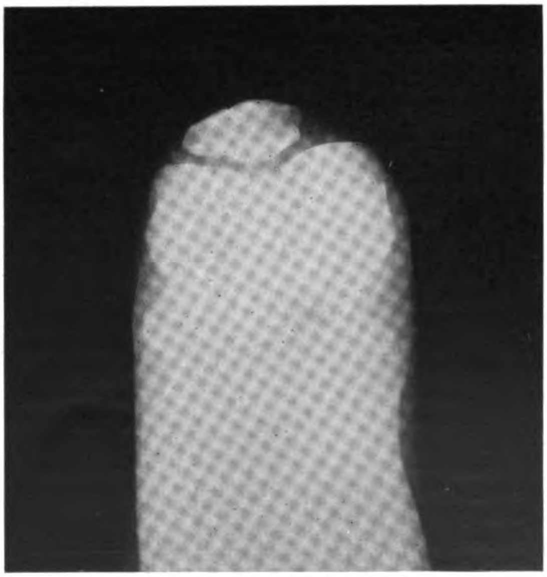


FIG. 273b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—12 centimeters
- If the knee is in a dry cast add 8 kilovolts peak
- If the knee is in a wet cast add 12 kilovolts peak
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 56 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 25 milliampere-seconds, 40-inch distance, 50 kilovolts peak

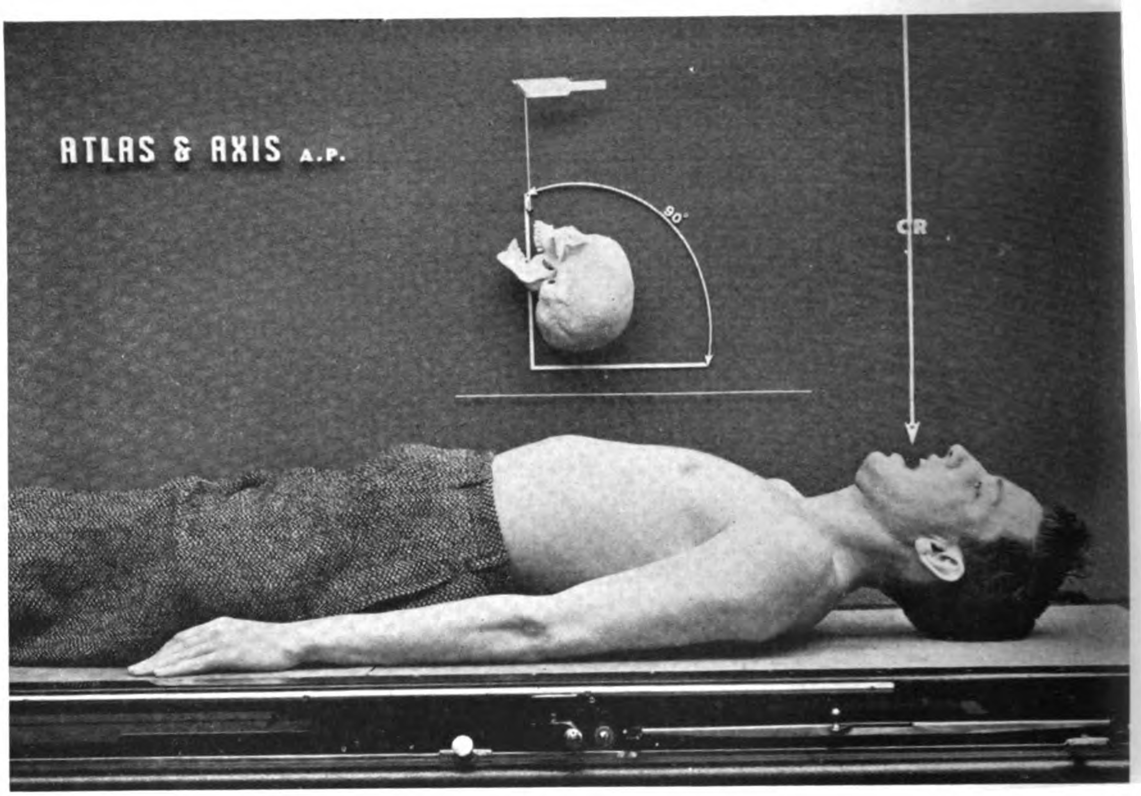


FIG. 274a

Atlas and Axis, Antero-Posterior

The patient is placed on the table in the supine position with the median line of the body over the centerline of the table. The chin is elevated until the occlusal surface of the teeth is vertical to the table top. With the mouth wide open, the film is centered to the separation of the upper and lower lip, from the side of the table. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—16 centimeters. Point of measurement—from the corner of the open mouth to the back of the neck
- Average variation in kilovolts peak minimum to maximum thickness for this part—9 kilovolts peak with Parspeed screens
- Because of the close focal-film distance, use either a lead diaphragm or a small short cone
- The patient is asked to stop breathing and swallowing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 50 milliampere-seconds, 20-inch distance, 48 kilovolts peak

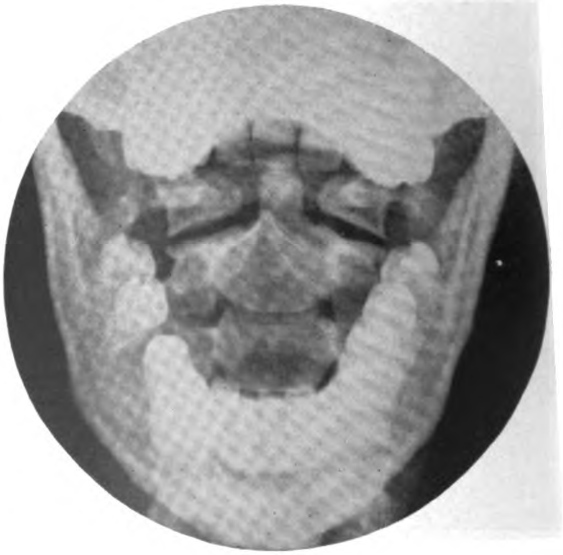


FIG. 274b

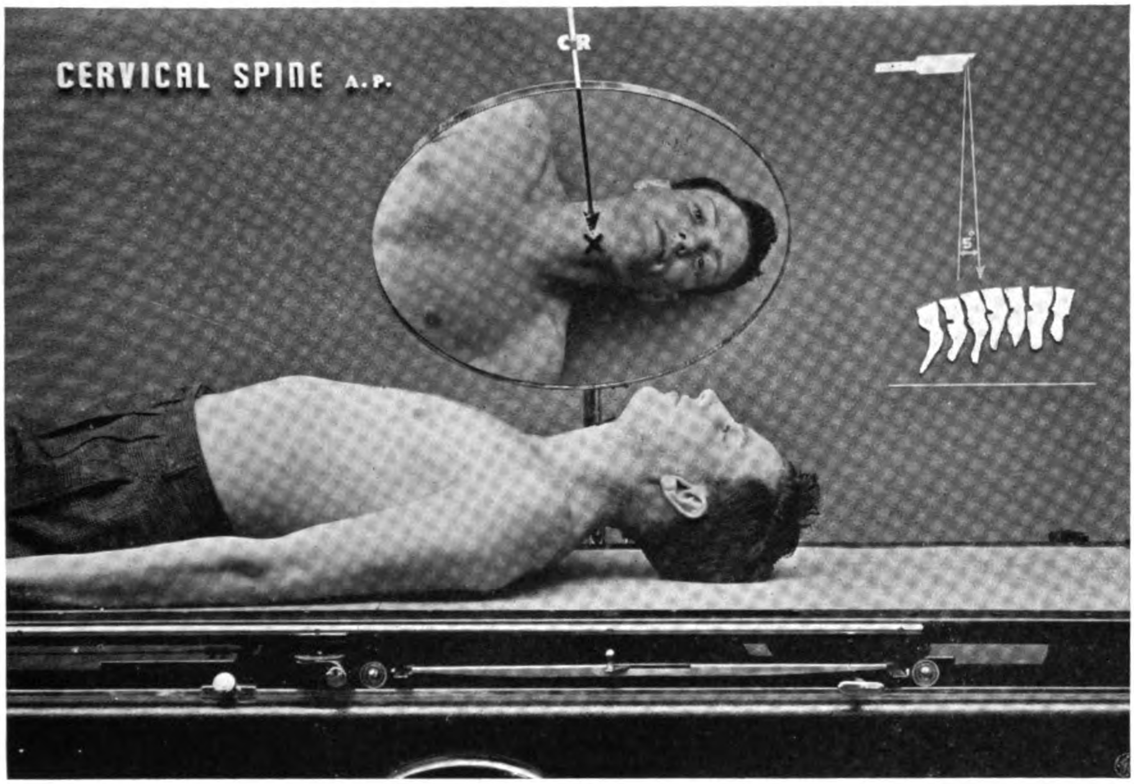


FIG. 275a

Cervical Spine, Antero-Posterior

The patient is placed in the supine position with the median line of the body over the centerline of the table. The chin is elevated until the inferior border of the mandible is vertical to the table top. With the tube tilted 5 degrees toward the patient's head, the central ray is directed to a point on the median line halfway between the mandibular symphysis and the superior border of the manubrium. The film is centered to the central ray.

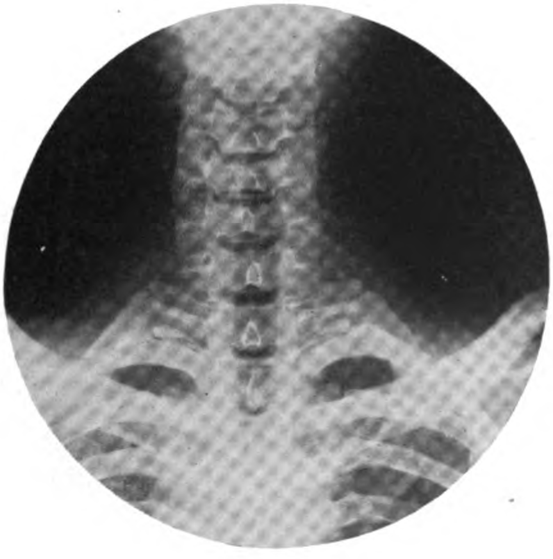


FIG. 275b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—13 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing and swallowing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 50 kilovolts peak

Cervical Spine, Lateral

Whenever possible, a six-foot focal-film distance should be employed for this view of the cervical spine. The patient may be in either the standing or sitting position with one shoulder resting against the cassette holder. The chin is elevated and the shoulders are pulled down and back. A point approximately three inches below the external auditory meatus is placed over the center of the film. The central ray is directed to the center of the film.

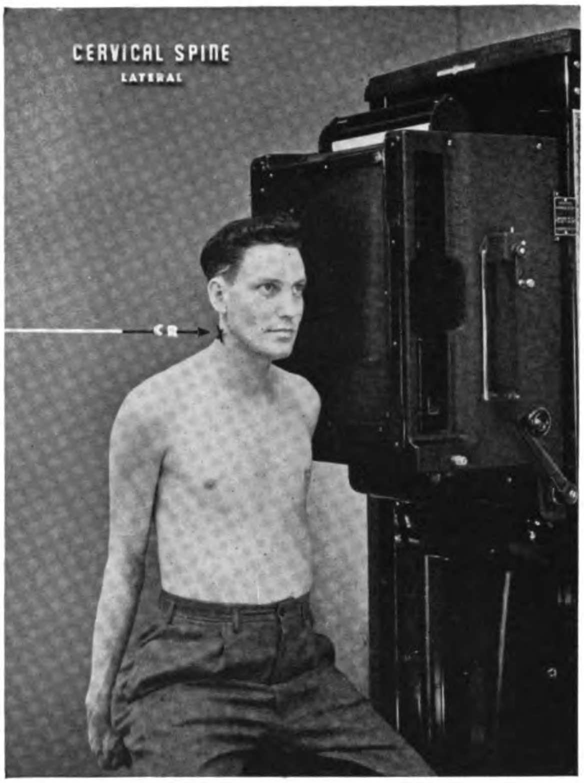


Fig. 276a

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—11 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—12 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing and swallowing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 72-inch distance 54 kilovolts peak

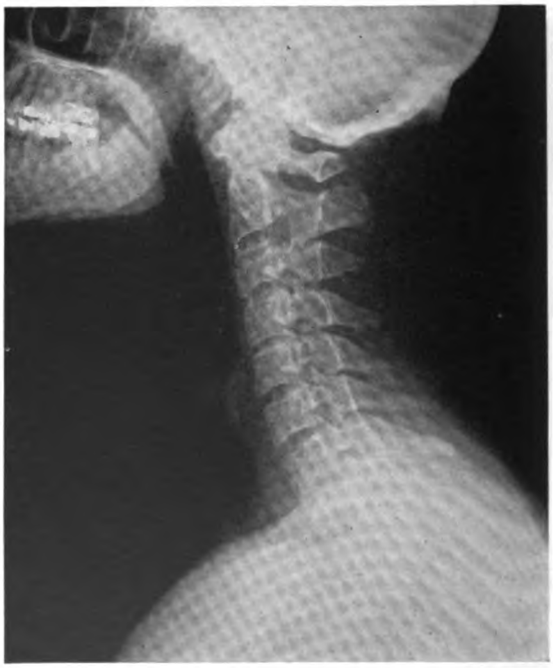


Fig. 276b

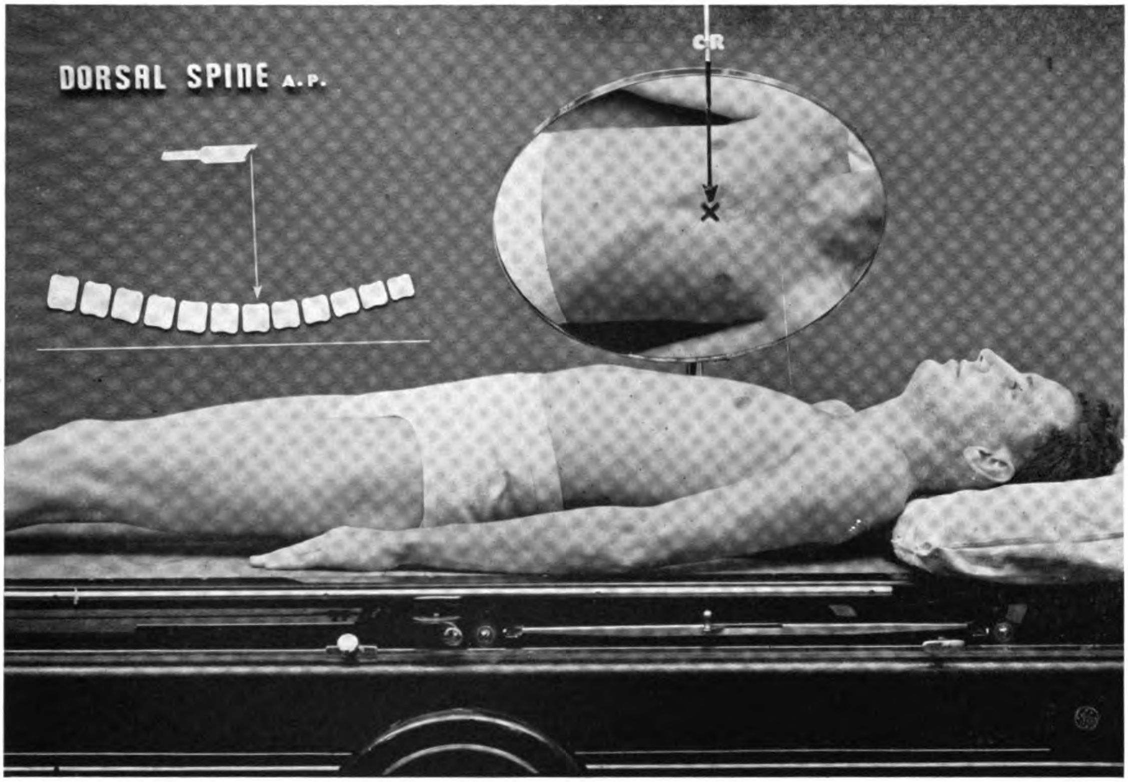


FIG. 277a

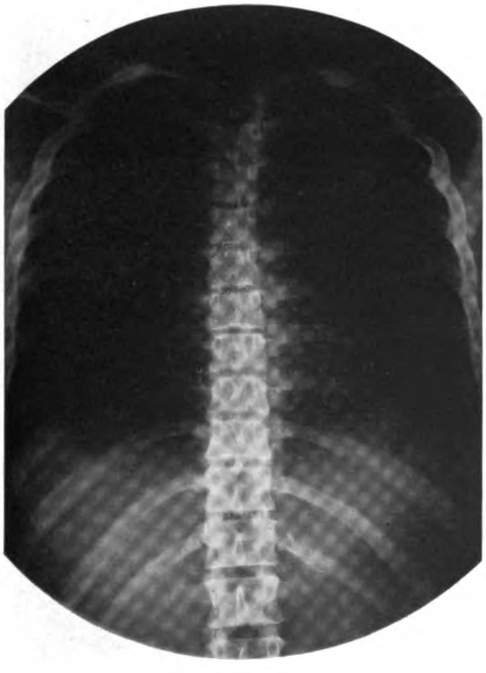


FIG. 277b

Dorsal Spine, Antero-Posterior

The patient is placed on the table in the supine position with the arms at the sides. The median line of the body is placed over the center-line of the table. From the side of the table the film is centered to a point on the median line halfway between the superior border of the manubrium and the inferior tip of the xyphoid process. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—21 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- If the entire spine is not desired, a small cone is recommended
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 64 kilovolts peak

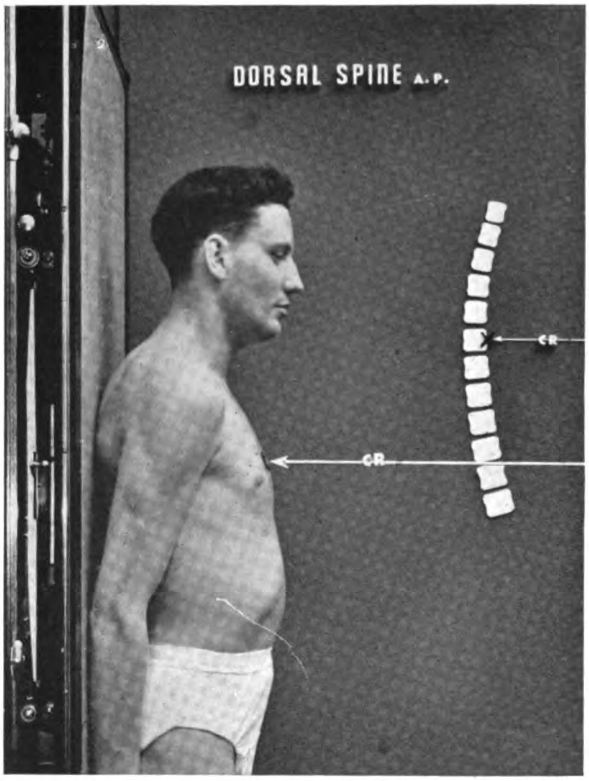


FIG. 278a

Dorsal Spine, Antero-Posterior, Upright

The patient is placed in the standing position with the back against the table, arms at the sides, and with the median line in front of the table centerline. From the side of the table the film is centered to a point on the median line halfway between the superior border of the manubrium and the inferior tip of the xyphoid process. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—21 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- If the entire spine is not desired, a small cone is recommended
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 64 kilovolts peak

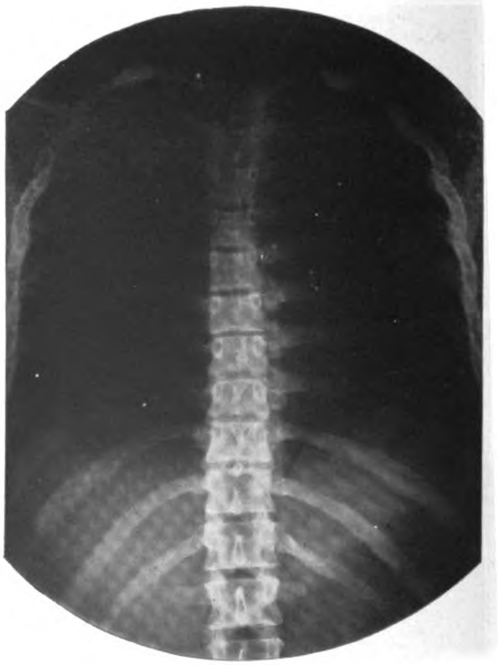


FIG. 278b

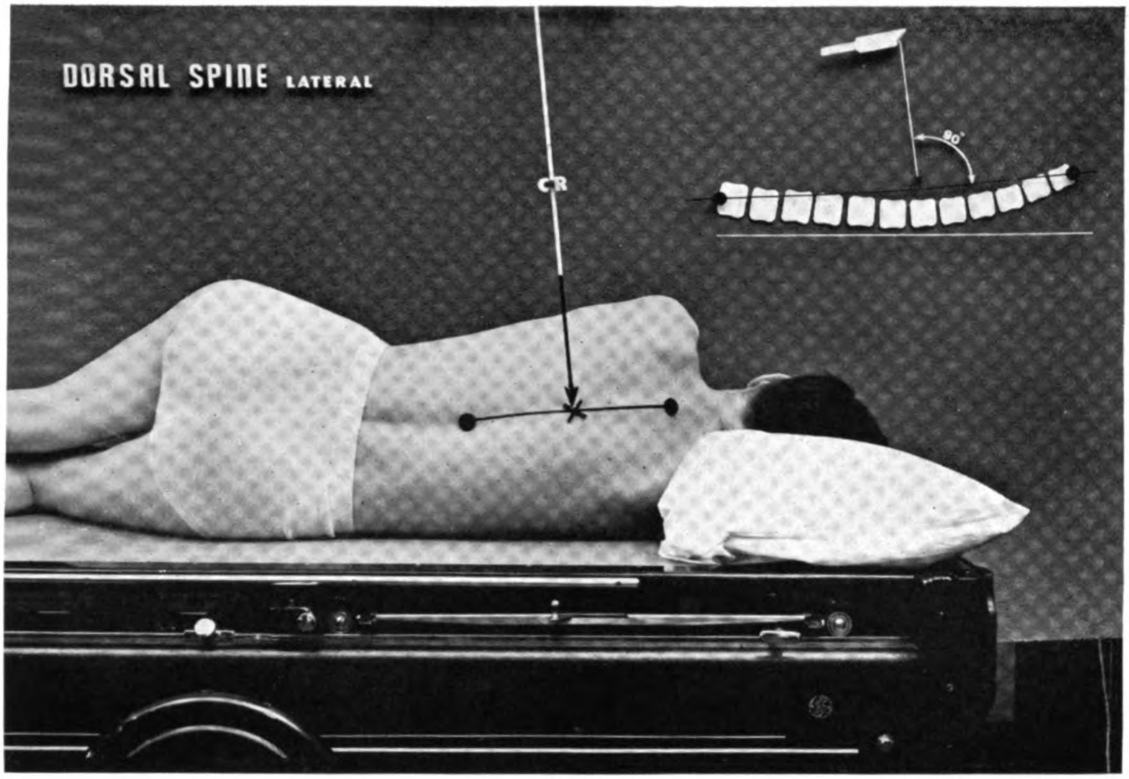


FIG. 279a

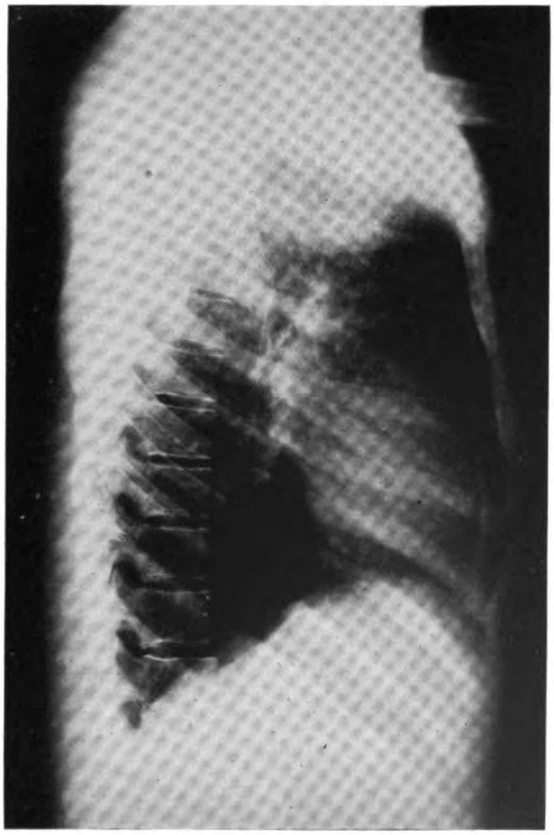


FIG. 279b

Dorsal Spine, Lateral

The patient is placed on the table in the lateral position wih the back toward the front of the table. The knees are flexed and the arms extended forward. The long axis of the spine is placed over the centerline of the table. A line is drawn on the posterior surface between the first and twelfth vertebrae. The tube is tilted until the central ray bisects this line at right angles. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—30 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- If the entire spine is not desired, a cone is recommended
- The patient should take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 64 kilovolts peak

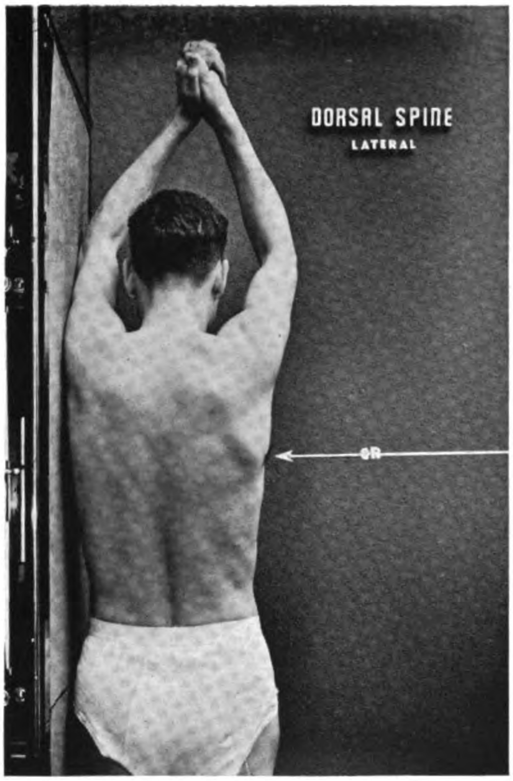


FIG. 280a

Dorsal Spine, Lateral, Upright

The patient is placed in the standing position with one side against the table top. The arms are brought forward and upward. The long axis of the spine is placed over the centerline of the table. From the side of the table the film is centered to a point halfway between the superior border of the manubrium and the inferior tip of the xyphoid process. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—30 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- If the entire spine is not desired, a cone is recommended
- The patient should take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 68 kilovolts peak

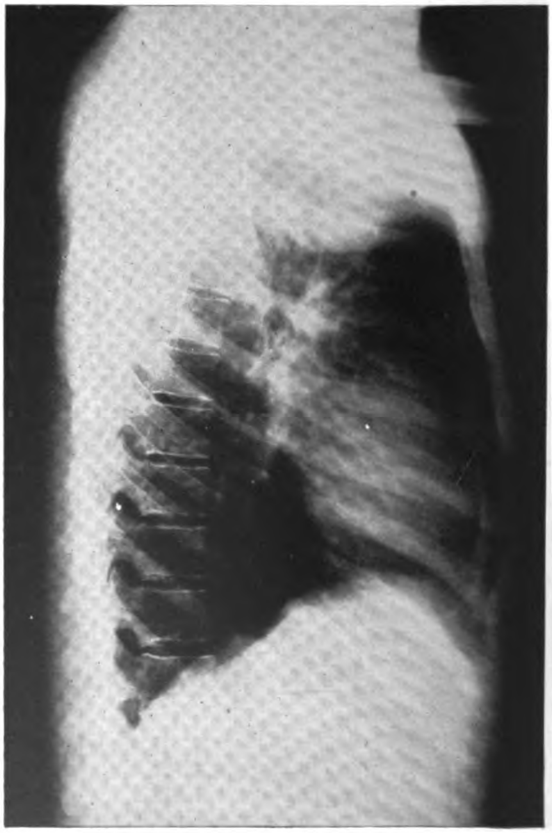


FIG. 280b

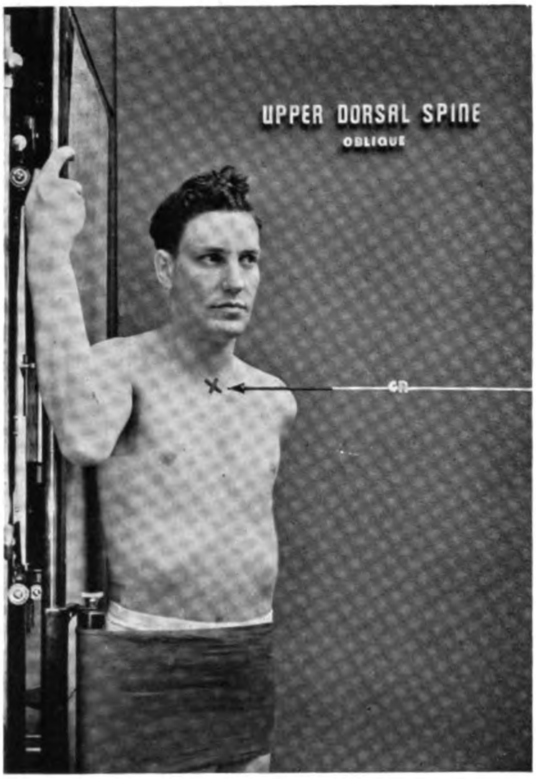


FIG. 281a

Upper Dorsal Spine, Oblique, Upright

The patient is placed in the lateral position against the table top. The pelvis is immobilized with the compression band and the shoulders are rotated to the oblique position. The upper arm is placed behind the back with the hand grasping the side of the table. The shoulder next to the table is brought forward so that a portion of the back rests against the table top. The long axis of the spine is placed over the table centerline. From the side of the table the film is centered to the superior border of the manubrium. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—26 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- If the entire spine is not desired, a cone is recommended
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 68 kilovolts peak

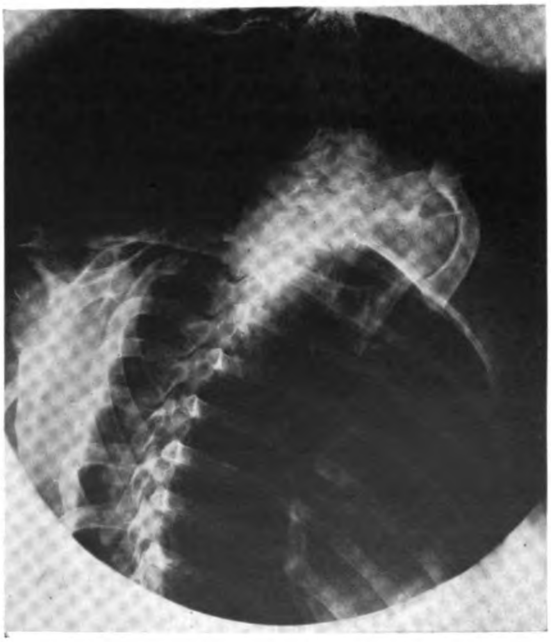


FIG. 281b

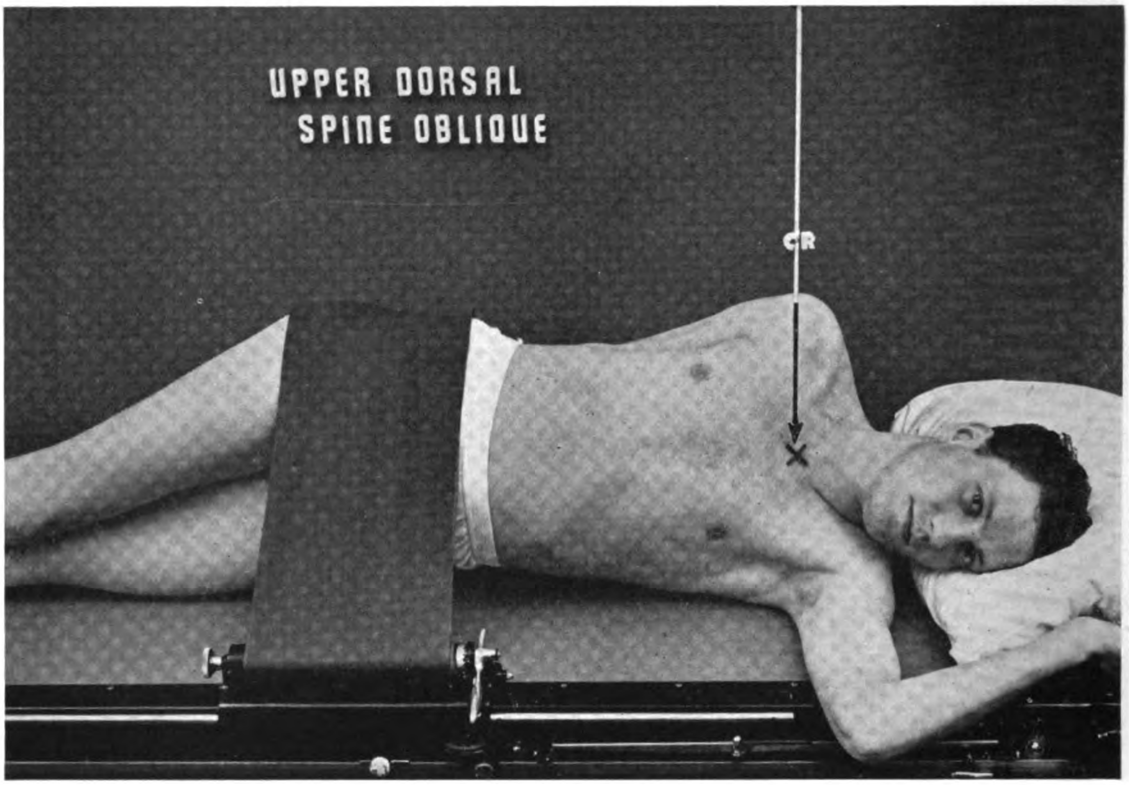


FIG. 282a

Upper Dorsal Spine, Oblique

The patient is placed in the lateral position facing the front of the table. The pelvis is immobilized with the compression band and the shoulders are rotated to the oblique position. The upper arm is placed behind the patient's back with the hand grasping the side of the table. The shoulder next to the table is drawn out from under the patient so that the body rests more on the back than on the shoulder. The long axis of the spine is placed over the table centerline. From the side of the table the film is centered to the superior border of the manubrium. The central ray is directed to the center of the film.

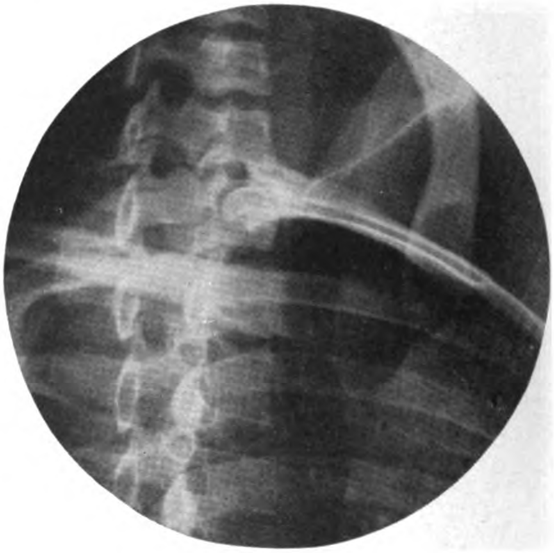


FIG. 282b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—21 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- If the entire spine is not desired, a small cone is recommended
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 64 kilovolts peak

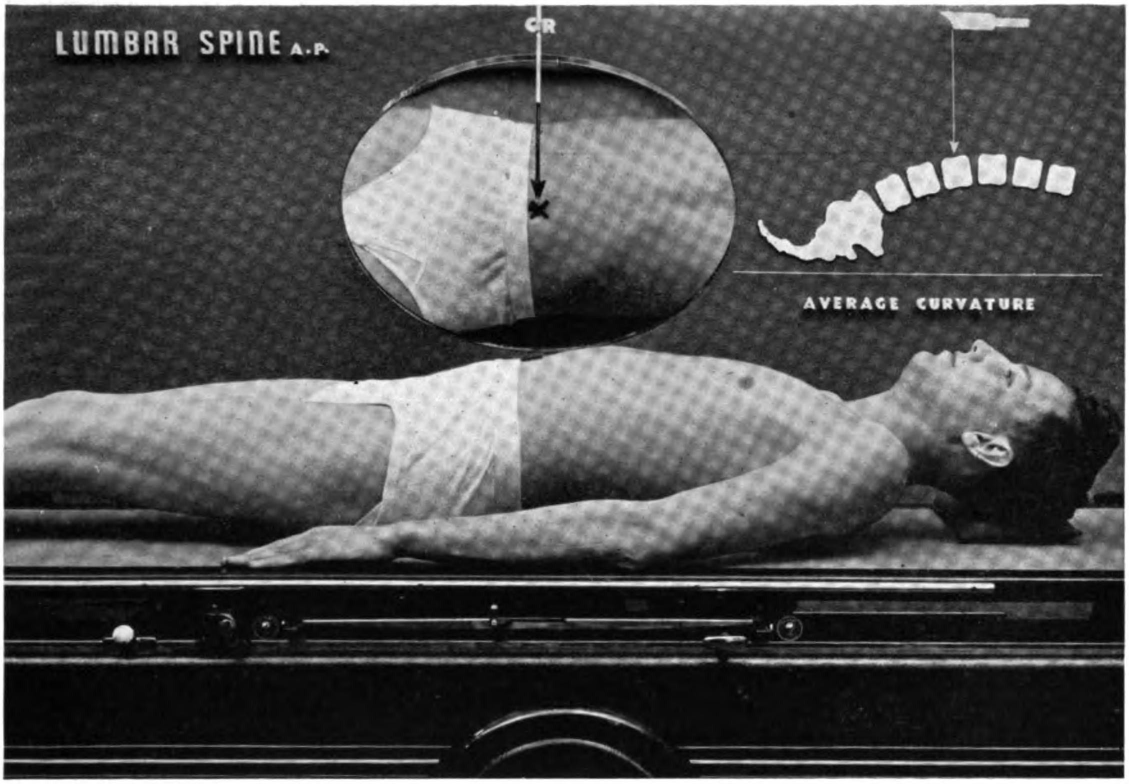


FIG. 283a

Lumbar Spine, Antero-Posterior

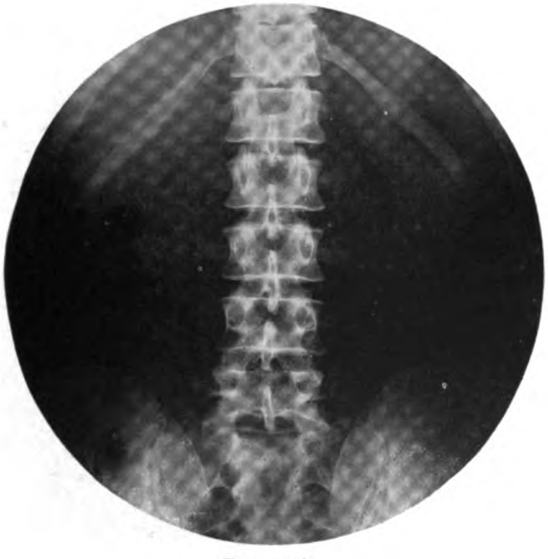


FIG. 283b

The patient is placed in the supine position, arms at the side with the median line of the body over the centerline of the table. From the side of the table the film is centered to a point on the median line halfway between the lower tip of the xyphoid process of the sternum and a line drawn through the anterior superior iliac spines. The central ray is directed to the center of the film.

Examination of the radiograph will show that there is poor separation of the vertebral bodies, due to the natural curvature of the spine. Because of this, the above position should be used only when it is impractical to manipulate the patient.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters.
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- If the part is in a dry cast add 8 kilovolts peak
- If the part is in a wet cast add 12 kilovolts peak
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure

- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 58 kilovolts peak

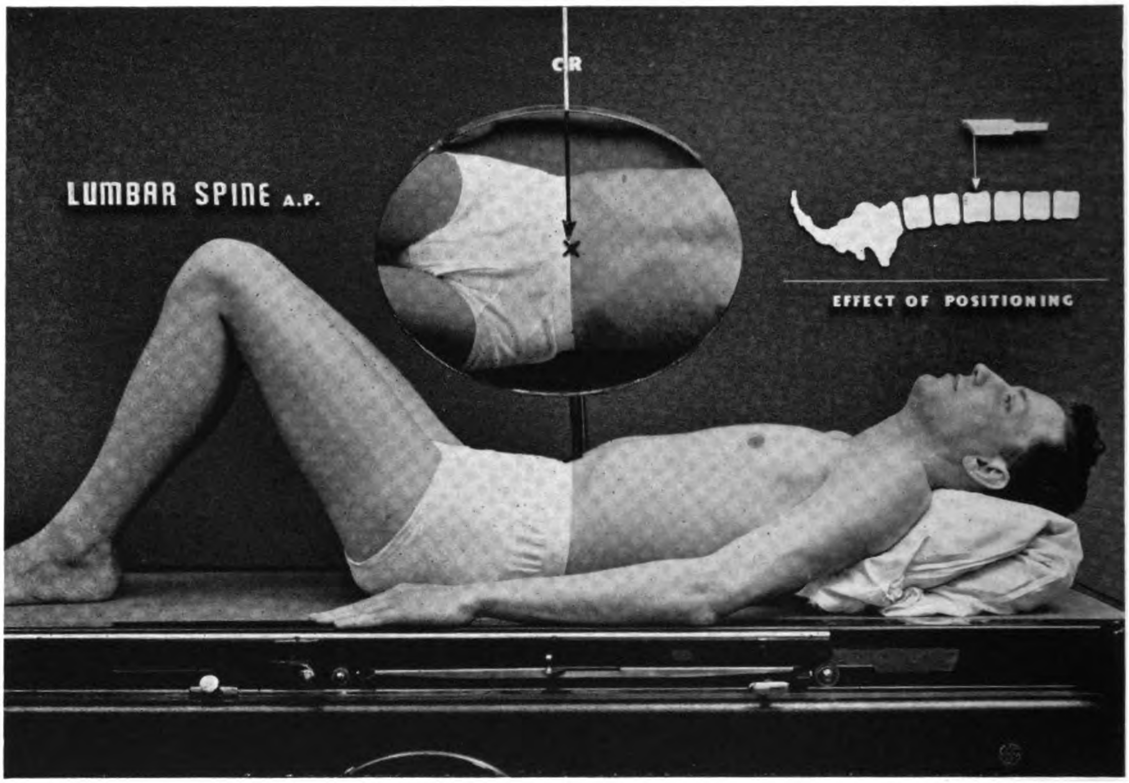


Fig. 284a

Lumbar Spine, Antero-Posterior

The patient is placed in the supine position with the arms at the side and the median line of the body over the centerline of the table. The knees are raised and the shoulders are elevated (with a pillow). When it is practical to manipulate the patient in this manner, it makes this position the one of choice, as it tends to straighten the natural curvature of the spine, thus better demonstrating the intervertebral spaces. From the side of the table the film is centered to a point halfway between the lower tip of the xyphoid process and a line between the anterior superior iliac spines. The central ray is directed to the center of the film.

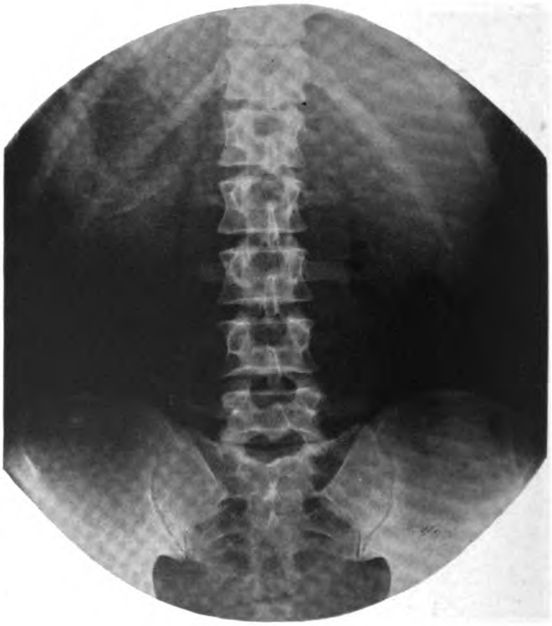


Fig. 284b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 62 kilovolts peak

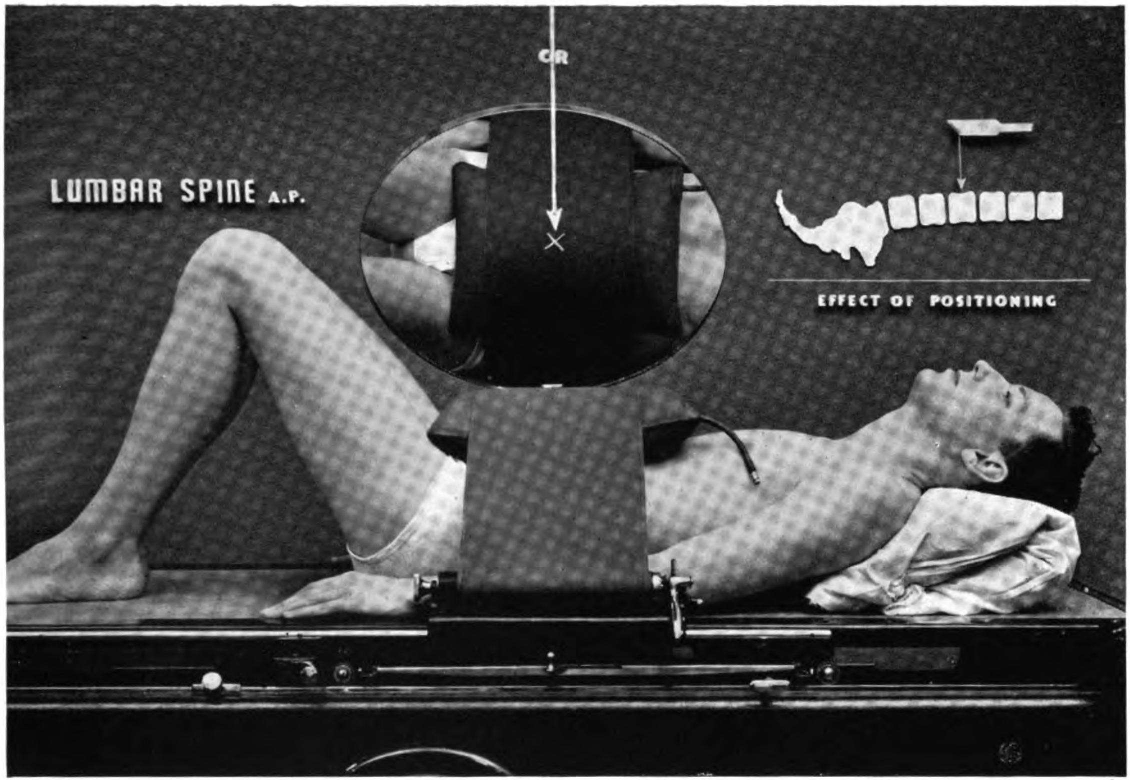


FIG. 285a

Lumbar Spine, Antero-Posterior

The relation of part to film and tube to film is the same as explained in the preceding position. Compression is applied at full expiration. The degree of compression applied is governed by the condition of the patient. The patient may breathe during the exposure. It will be noted that there is a reduction in kilovolts peak because of the reduction in the thickness of the part produced by compression.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 56 kilovolts peak

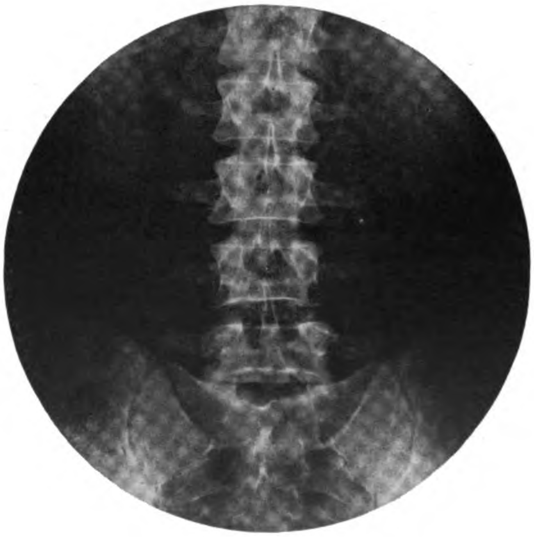
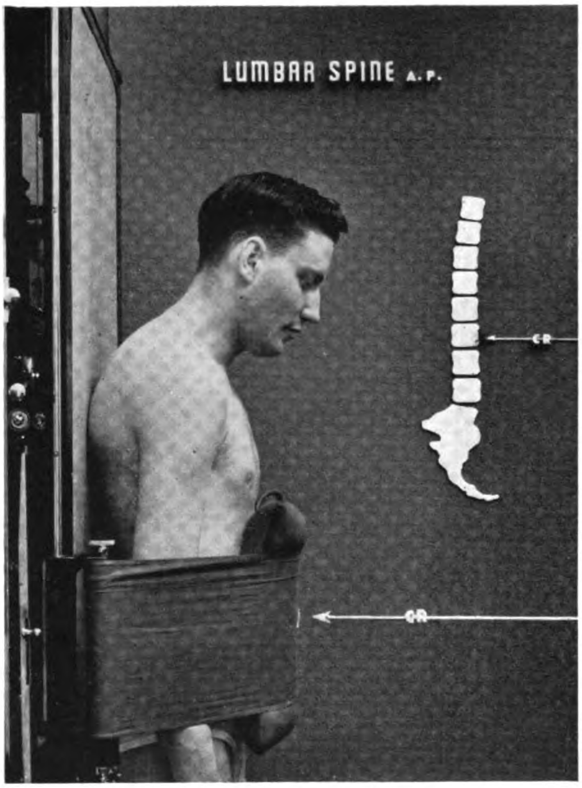


FIG. 285b



Lumbar Spine, Antero-Posterior, Upright

The patient is placed in the upright position with the back against the tabletop and with the median line in front of the table centerline. From the side of the table the film is centered to a point on the median line halfway between the lower tip of the xyphoid process and a line between the anterior superior iliac spines. A compression bladder and band are used whenever possible. The central ray is directed to the center of the film.

Fig. 286a

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 58 kilovolts peak

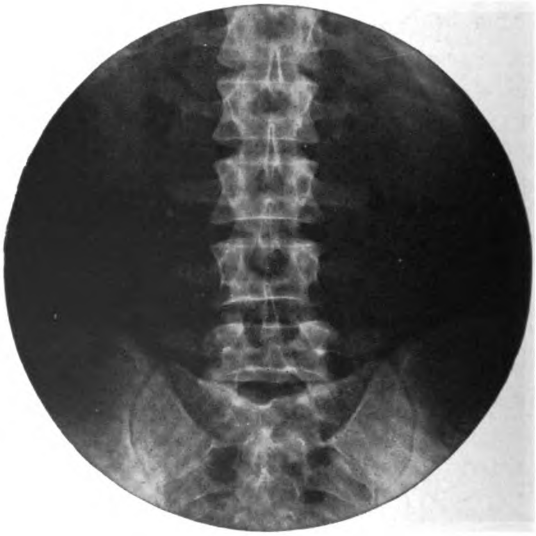


Fig. 286b

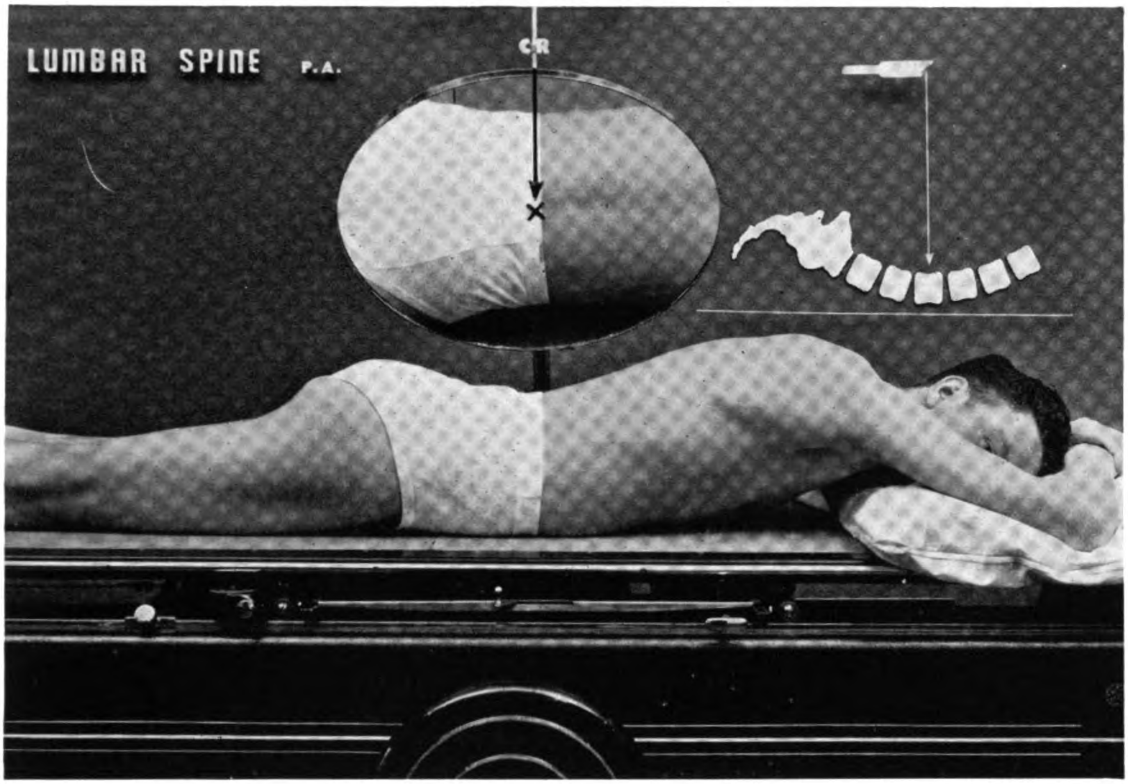


FIG. 287a

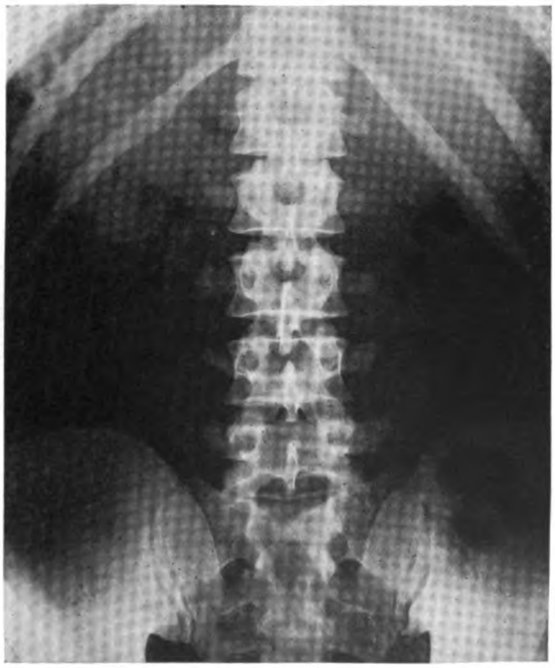


FIG. 287b

Lumbar Spine, Postero-Anterior

With the patient in the prone position, the hands are clasped above the head and the median line of the body is placed over the centerline of the table. The film is centered to the crest of the ilium from the side of the table. The central ray is directed to the center of the film. By taking advantage of the natural curvature of the spine, this position is of great value in demmonstrating the intervertebral spaces.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 56 kilovolts peak

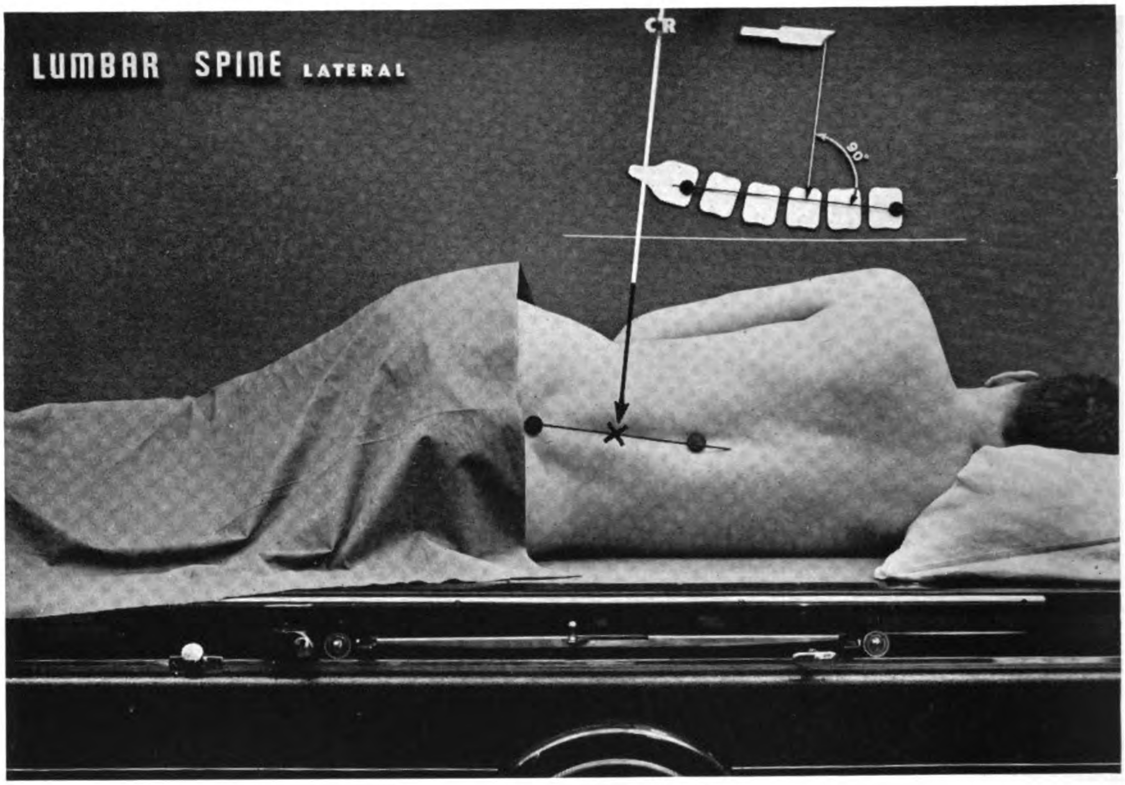


FIG. 288a

Lumbar Spine, Lateral

The patient is placed on the table in the lateral position, with the back towards the front of the table. The knees are flexed and the arms extended for support. The long axis of the spine is centered by placing the tips of the spinous processes three inches back of the centerline of the table. A line may be drawn on the posterior surface of the body between the first lumbar and the junction of the fifth and sacrum. The tube is tilted until the central ray bisects this line at right angles. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—28 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—24 kilovolts peak with Parspeed screens
- If the part is in a dry cast add 8 kilovolts peak
- If the part is in a wet cast add 12 kilovolts peak
- The patient is asked to stop breathing during the exposure if possible
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 300 milliampere-seconds, 40-inch distance, 74 kilovolts peak

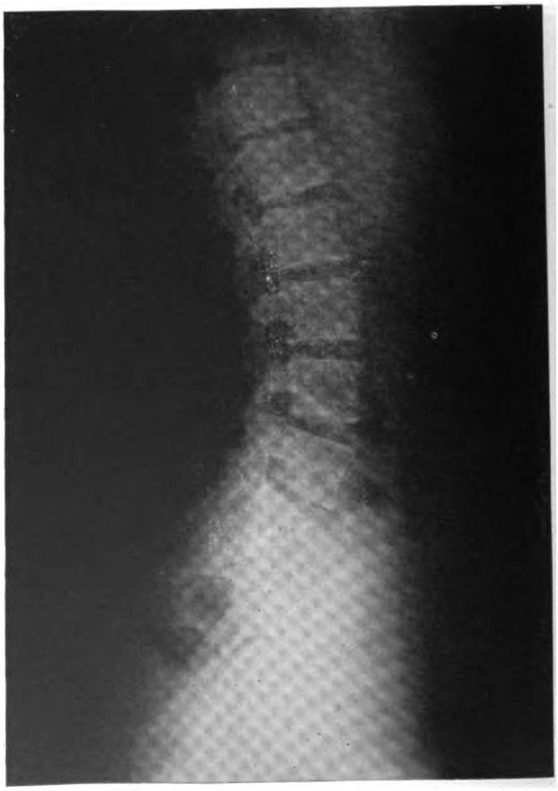


FIG. 288b

Lumbar Spine, Lateral, Upright

The patient is placed in the upright position with one side resting against the table top. The arms are raised and the clasped hands are placed over the head. The long axis of the spine is centered by placing the tips of the spinous processes three inches back of the table centerline. From the side of the table the film is centered to the crest of the ilium. The central ray is directed to the center of the film. Ordinarily no tube tilt is required for the upright position.

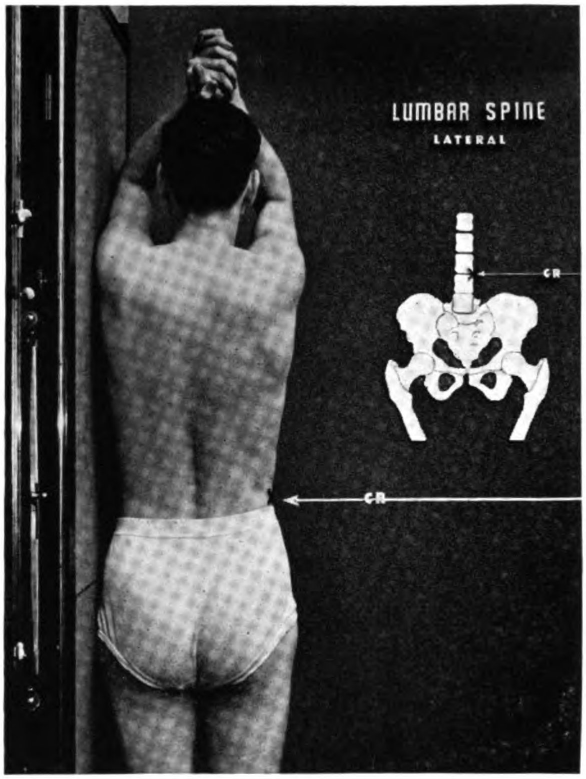


FIG. 289a

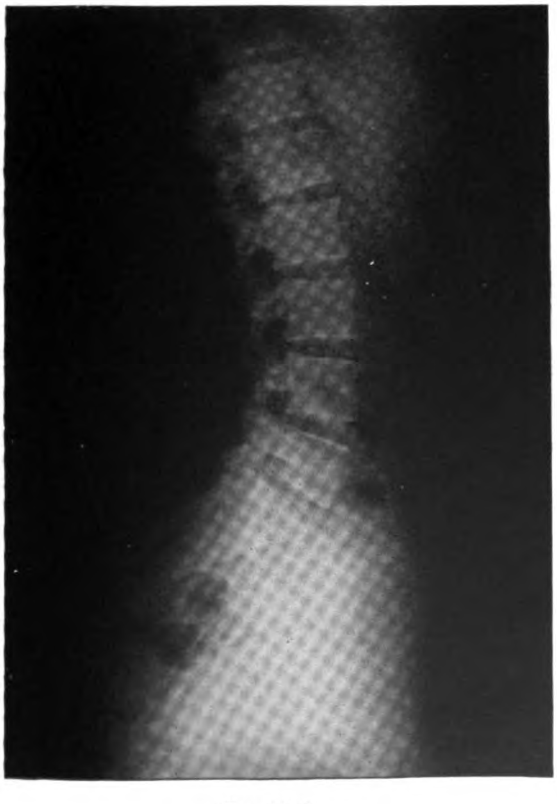


FIG. 289b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation in this chart—28 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—24 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure, if possible
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 300 milliampere-seconds, 40-inch distance, 78 kilovolts peak

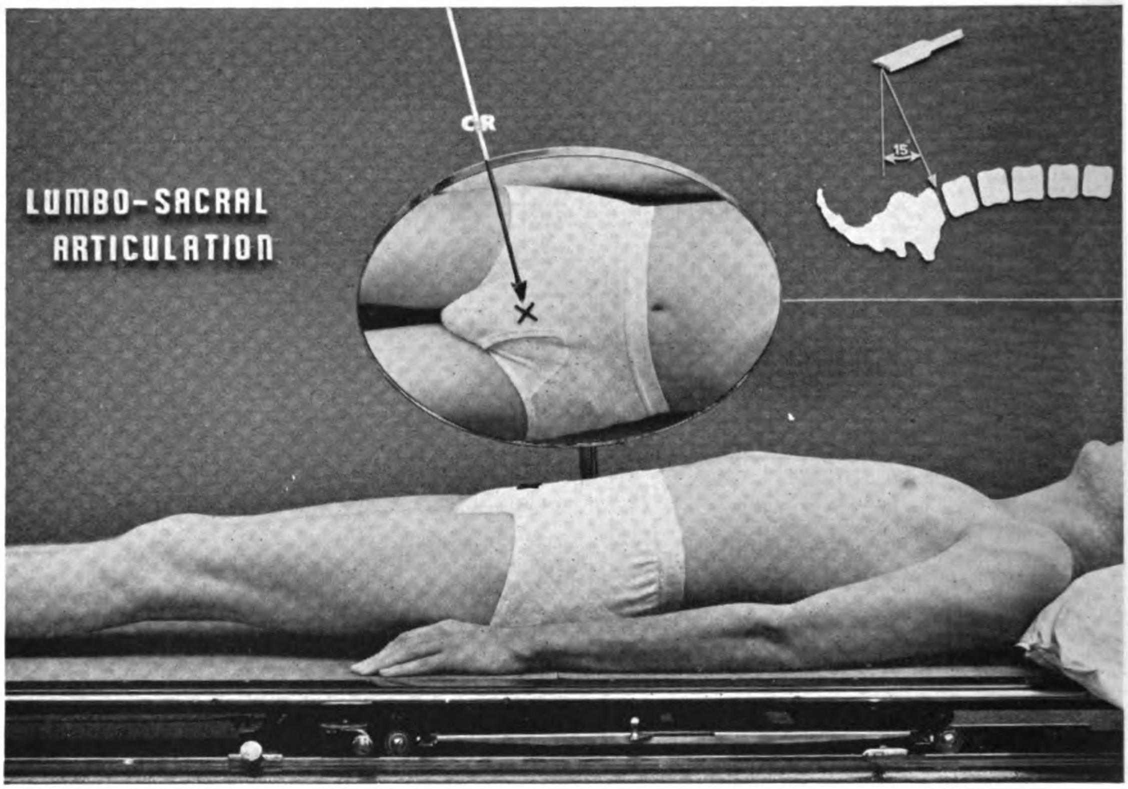


Fig. 290a

Lumbo-Sacral Articulation, Antero-Posterior

The patient is placed in the supine position with the median line over the centerline of the table. With the tube tilted 15 degrees toward the patient's head, the central ray is directed to a point on the median line halfway between the superior margin of the pubic symphysis and a line between the anterior superior iliac spines. The film is centered to the central ray.

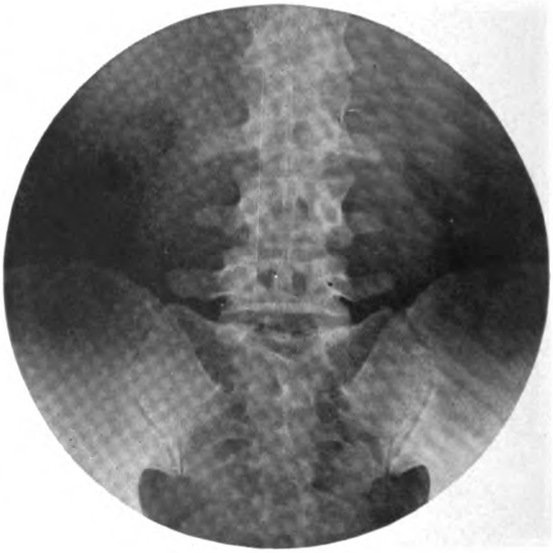


Fig. 290b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—19 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 60 kilovolts peak

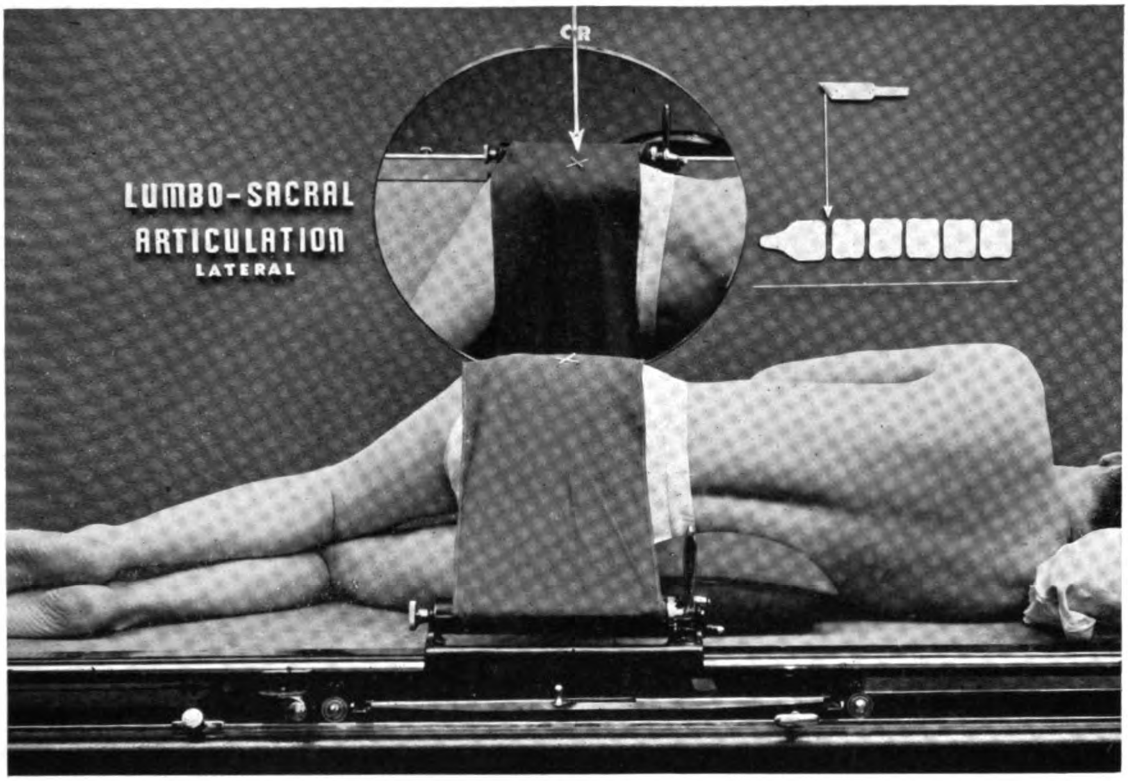


FIG. 291a

Lumbo-Sacral Articulation, Lateral

The patient is placed on the table in the lateral position. The knees are flexed to assist the patient in maintaining the position. A compression bladder or a pad of some non-opaque material is placed under the side of the body just below the ribs to straighten the spine. A point halfway between the anterior superior iliac spine and the posterior surface of the sacrum is placed over the centerline of the table. From the side of the table the film is centered to the anterior superior iliac spine. The central ray is directed to the center of the film.

If the lateral coccyx only is desired, the tube should be centered approximately two inches lower.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—32 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part

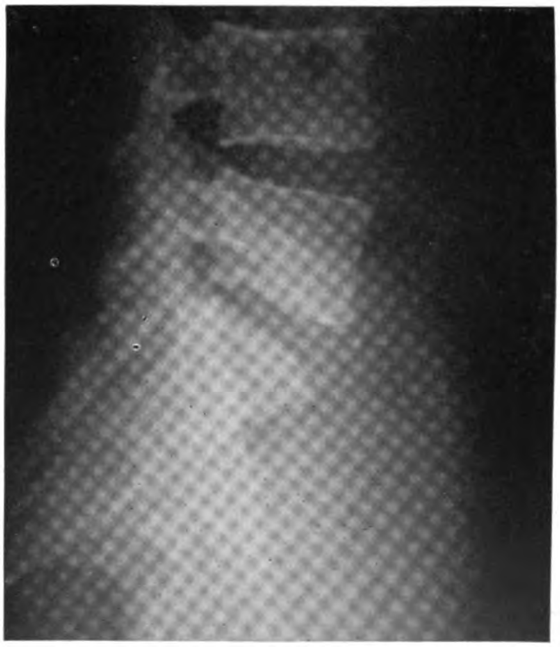


FIG. 291b

- The patient is asked to stop breathing during the exposure, if possible
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 300 milliampere-seconds, 30-inch distance, 74 kilovolts peak

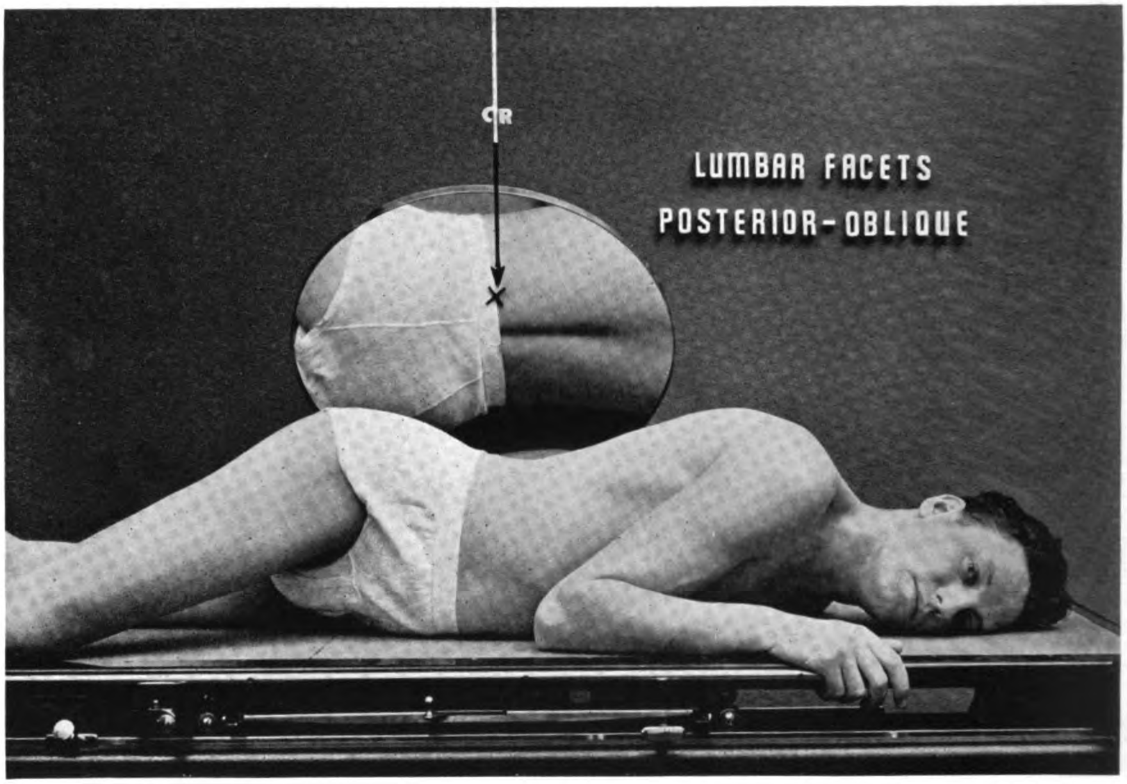


FIG. 292a

Lumbar Facets, Postero-Anterior Oblique

The patient is placed on the table in the prone position with the arms at the sides. If the right facets are to be radiographed, the patient is rotated 45 degrees to the left. This can be done by placing the right hand on the side of the table and flexing the right knee. This rotates the body and furnishes sufficient support to enable the patient to maintain the position. The long axis of the spine is placed over the centerline of the table. From the side of the table the film is centered to the crest of the ilium. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—26 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 68 kilovolts peak

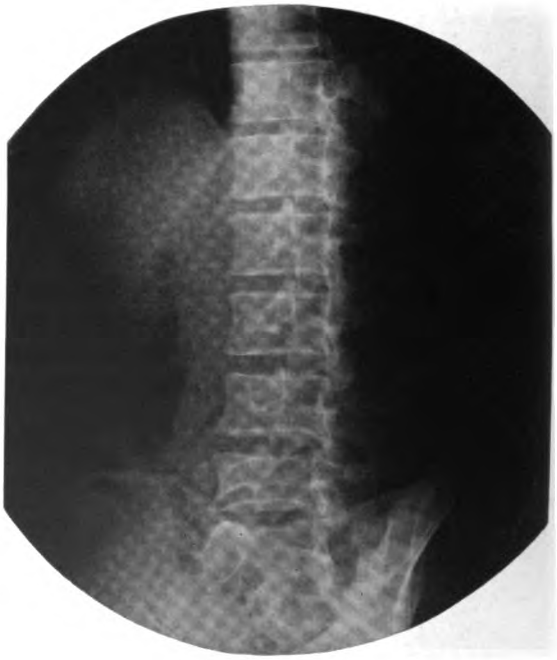


FIG. 292b

Lumbar Facets, Postero-Anterior Oblique, Upright

The patient is placed in the upright position facing the table. If the right facets are to be radiographed, the left side of the body rests against the table, and the right side is rotated until the body forms an angle of 45 degrees with the tabletop. The long axis of the spine is placed in front of the table centerline. From the side of the table the film is centered to the crest of the ilium. The central ray is directed to the center of the film.

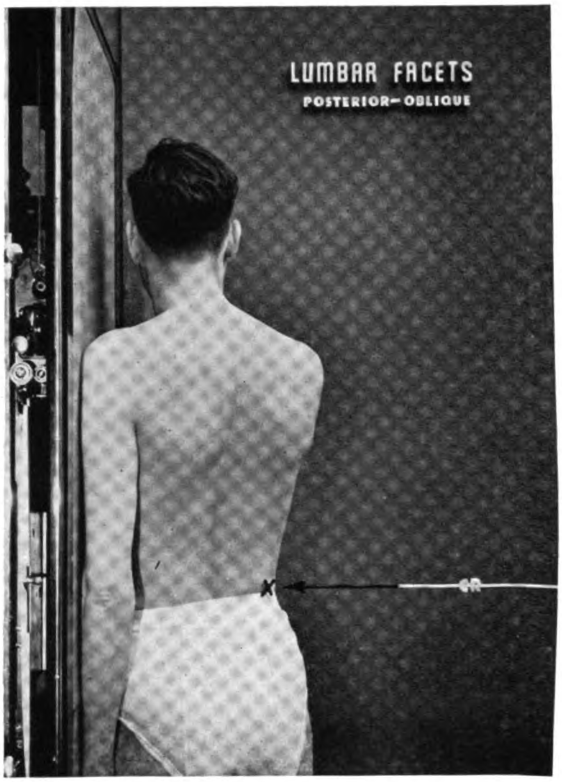


FIG. 293a

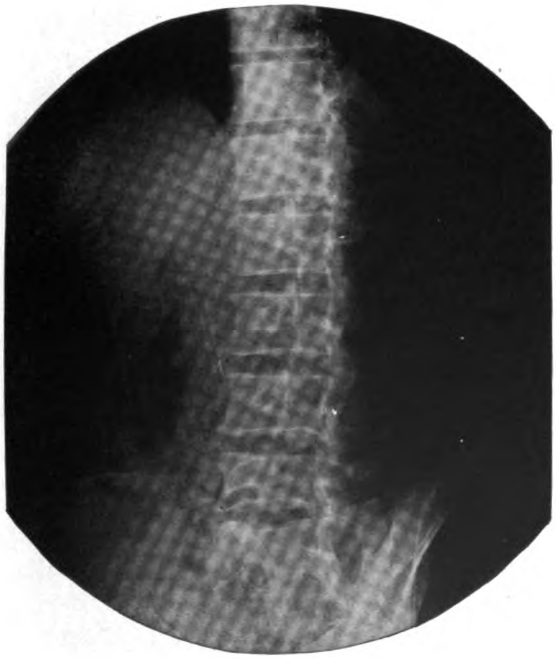


FIG. 293b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—22 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 62 kilovolts peak

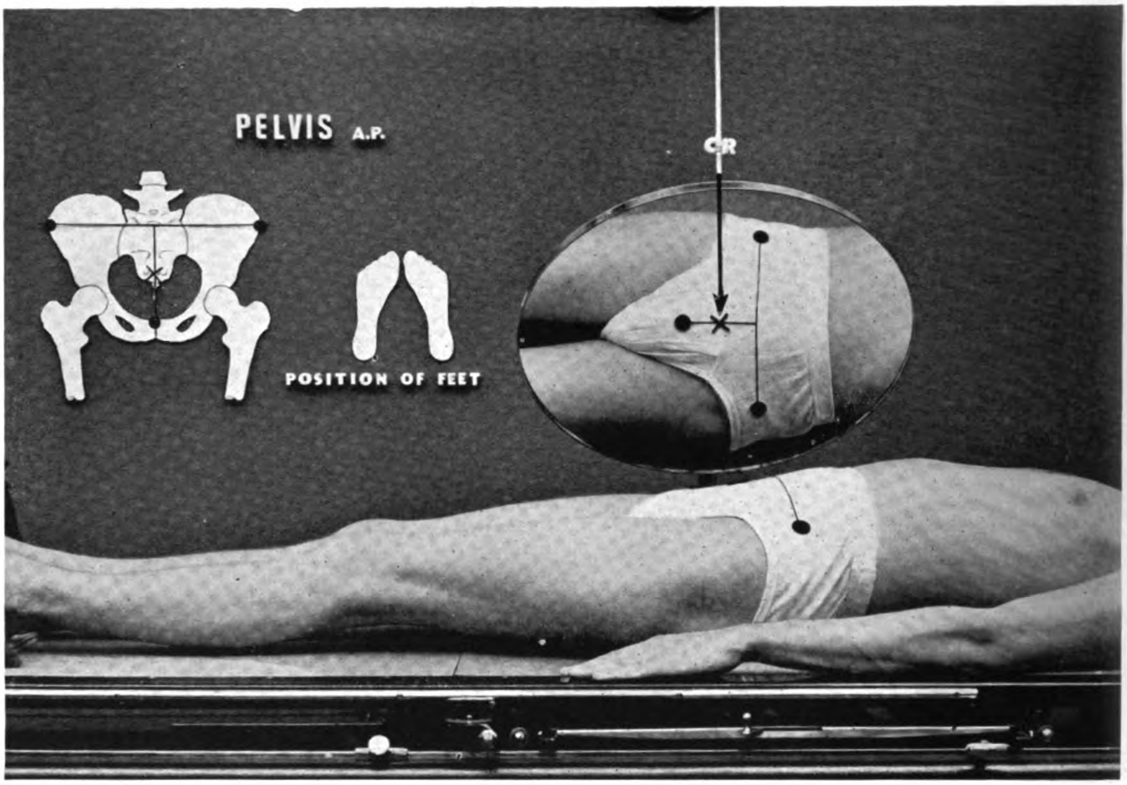


FIG. 294a

Pelvis, Antero-Posterior

With the patient in the supine position, the median line of the body is placed over the centerline of the table. When the greater trochanters are to be included, the feet should be placed so that the toes point upward. The film is placed crosswise and from the side of the table is centered to a point on the median line halfway between the superior margin of the pubic symphysis and a line drawn through the anterior superior iliac spines. When a portion of the lumbar spine region is to be included, the film is placed lengthwise, and from the side of the table is centered to a line drawn through the anterior superior iliac spines. In both cases the central ray is directed to the center of the film.

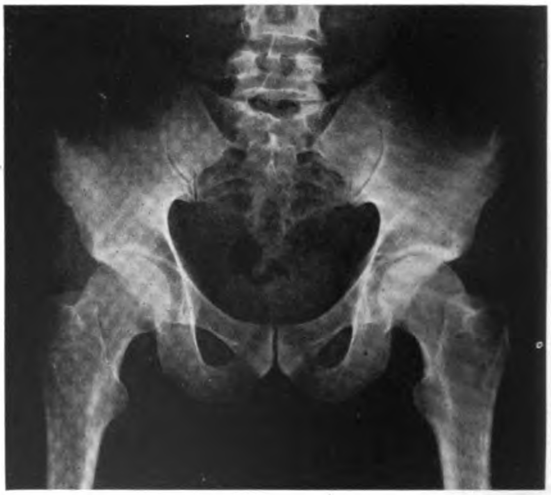


FIG. 294b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 58 kilovolts peak

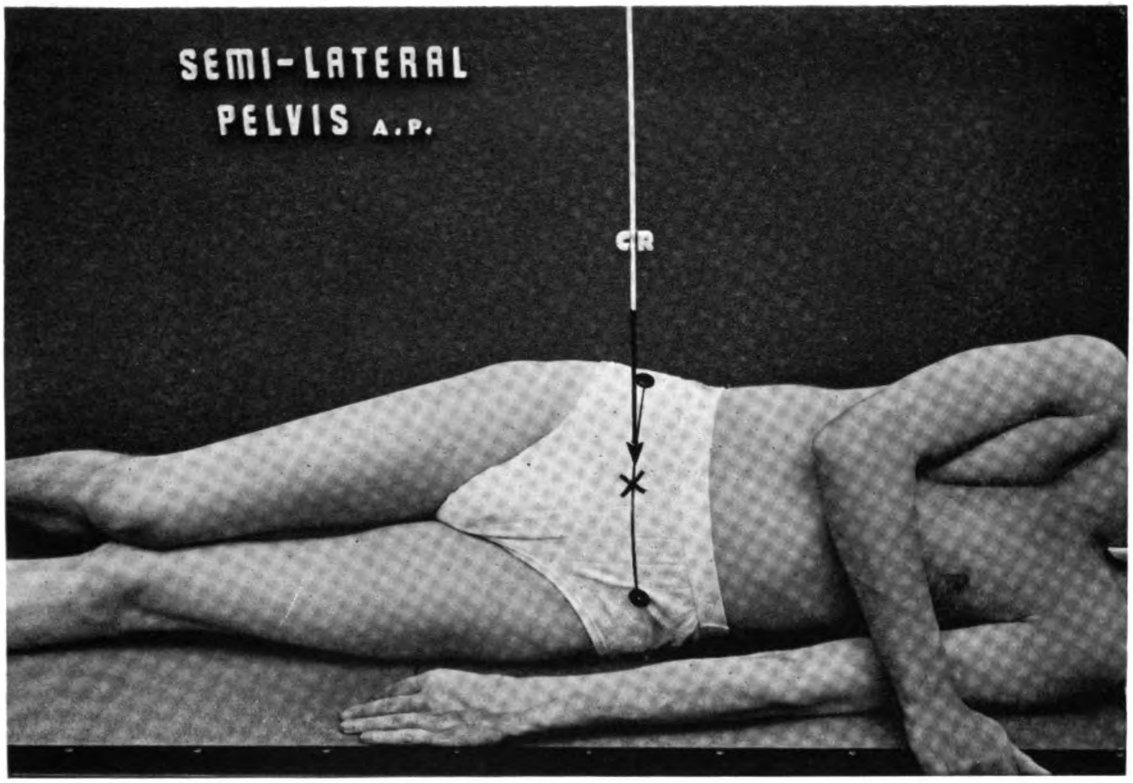


FIG. 295a

Pelvis, Semi-Lateral, Antero-Posterior

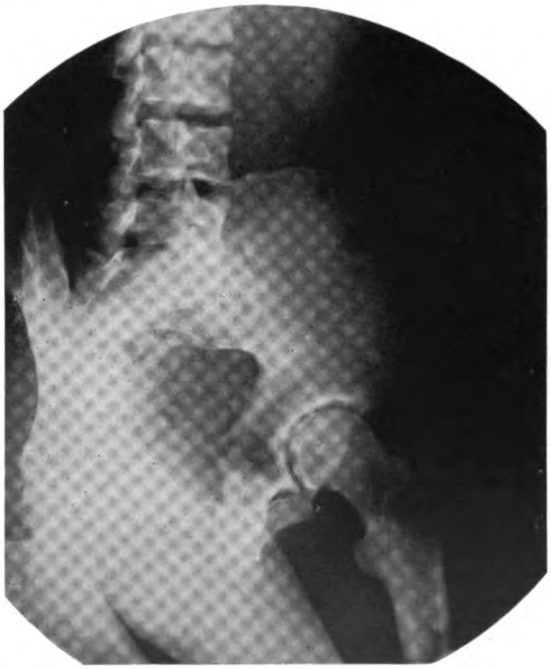


FIG. 295b

For the right semi-lateral pelvis, the patient is placed in the supine position and rotated toward the left side until the body is in the semi-lateral position. The patient may maintain this position by flexing the upper knee and resting the foot against sandbags or a compression device. The upper arm is brought forward with the hand holding the side of the table. The median line of the body is placed over the centerline of the table. From the side the film is centered to a line drawn through the two anterior superior iliac spines. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—24 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 70 kilovolts peak

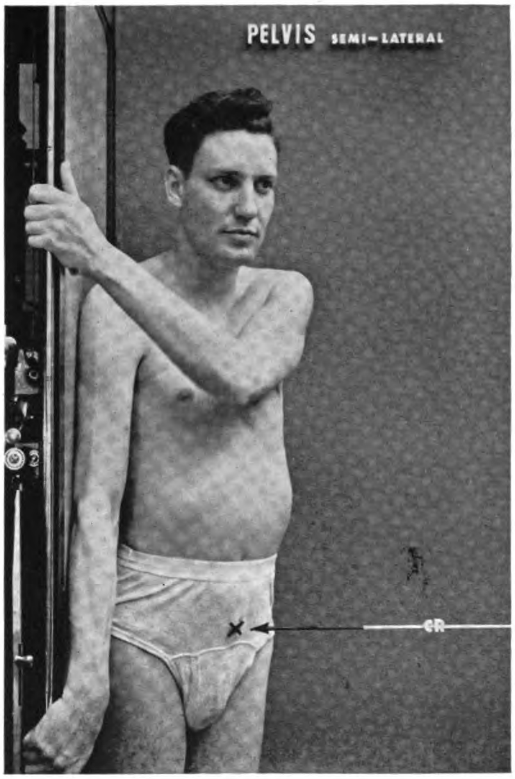


FIG. 296a

Pelvis, Semi-Lateral, Antero-Posterior, Upright

The patient is placed in the upright position with one side resting against the tabletop. Both hands grasp the front edge of the table. The body is rotated until it forms an angle of 45 degrees with the tabletop, with the median line placed in front of the table centerline. From the side of the table the film is centered to a line drawn through the two anterior superior iliac spines. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—24 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**

With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 70 kilovolts peak

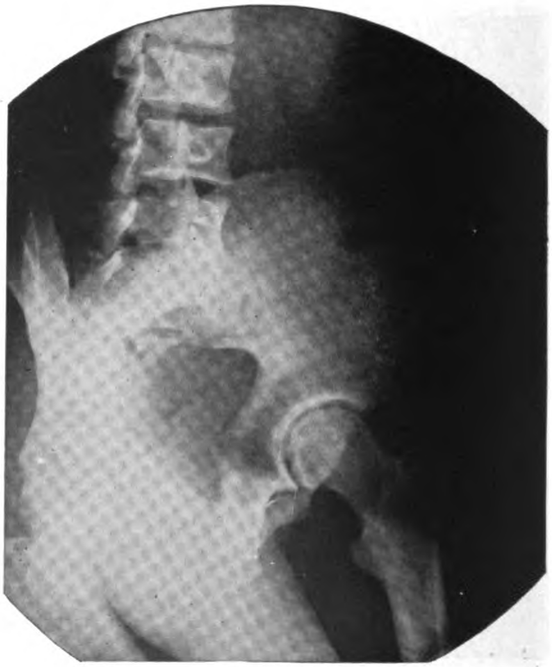


FIG. 296b

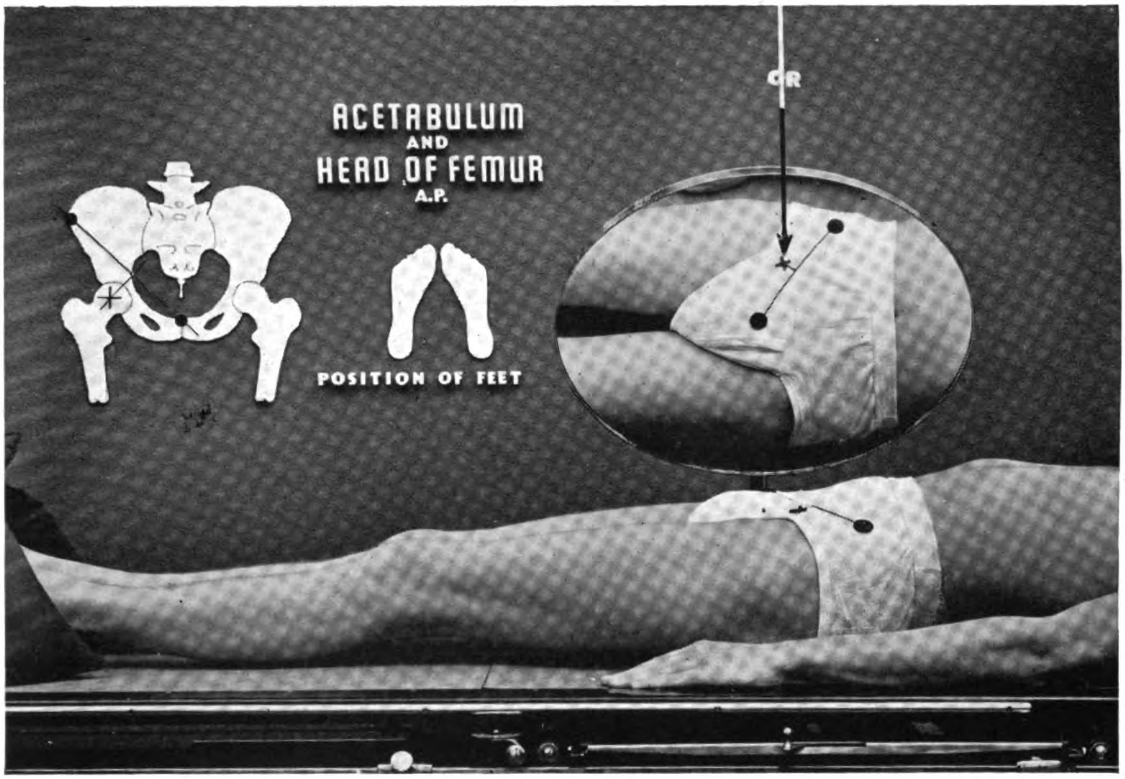


FIG. 297a

Acetabulum and Head of Femur, Antero-Posterior

The patient is placed in the supine position. The feet are supported by sandbags so that the toes point upward. To locate the centering point, a baseline is drawn between the anterior superior iliac spine and the superior margin of the pubic symphysis. A second line is drawn toward the thigh at right angles to and bisecting the baseline. A point on the second line one inch from the baseline becomes the centering point and is placed over the centerline of the table. The film and the central ray are centered to this point.

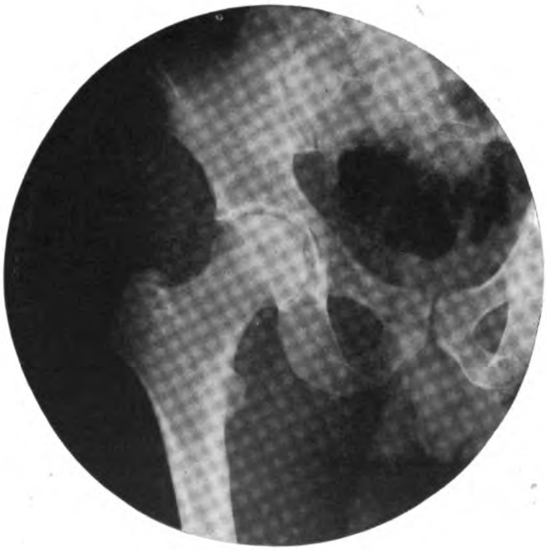


FIG. 297b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 58 kilovolts peak

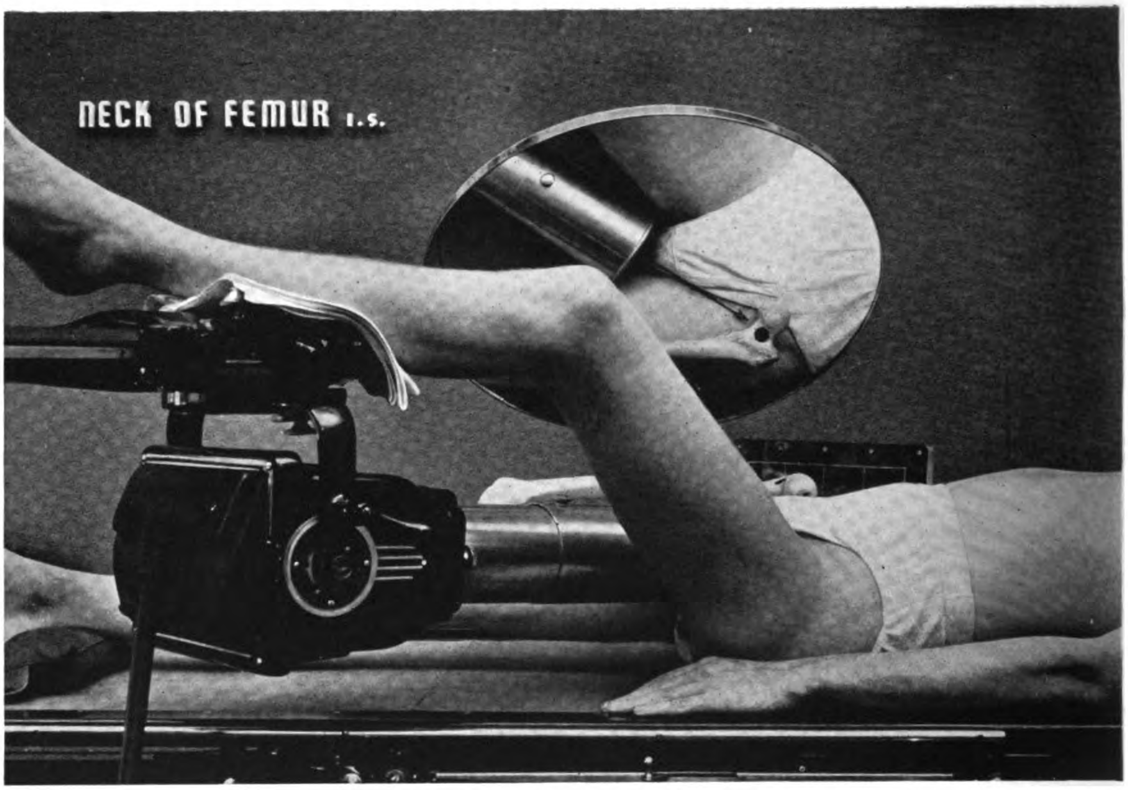


FIG. 298a

Neck of Femur, Infero-Superior

The following description is based on the use of a mobile type x-ray unit, or shock proof x-ray tube.

The cassette, supported by sandbags, is placed in contact with the side of the patient just over the crest of the ilium in such a manner that it will be parallel with the neck of the femur. The position of the neck can be determined by drawing a line from the head of the femur (see position for acetabulum) to the greater trochanter. The opposite leg is raised and supported by the tube arm and the central ray is directed through the upper third of the thigh, bisecting and at right angles to the neck of the femur.

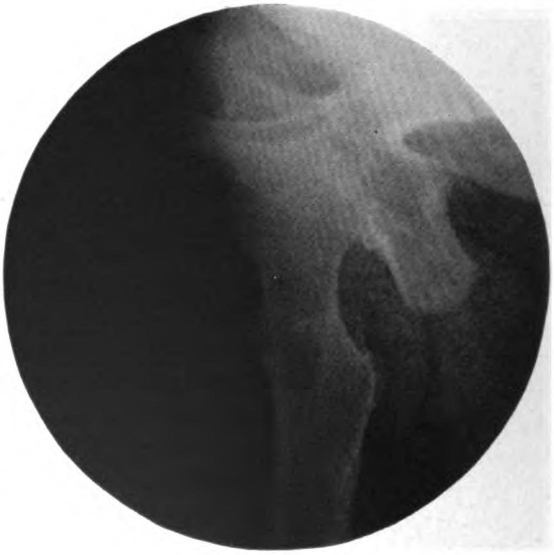


FIG. 298b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 44 kilovolts peak

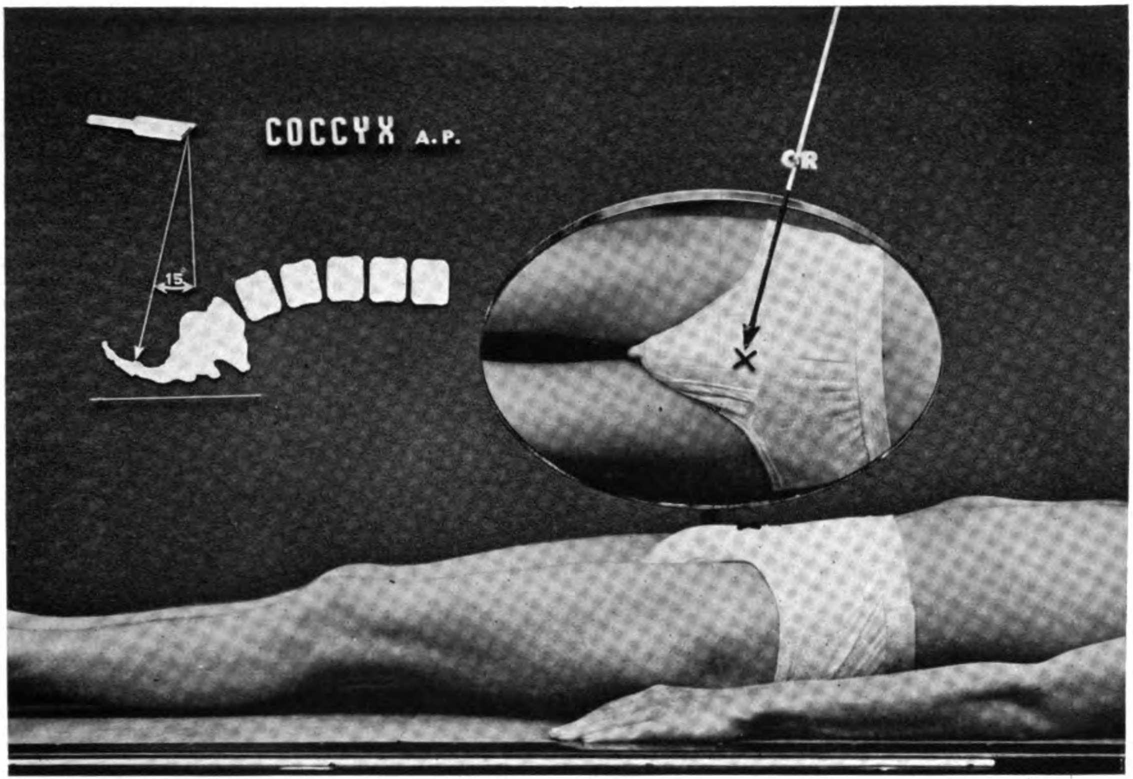


FIG. 299a

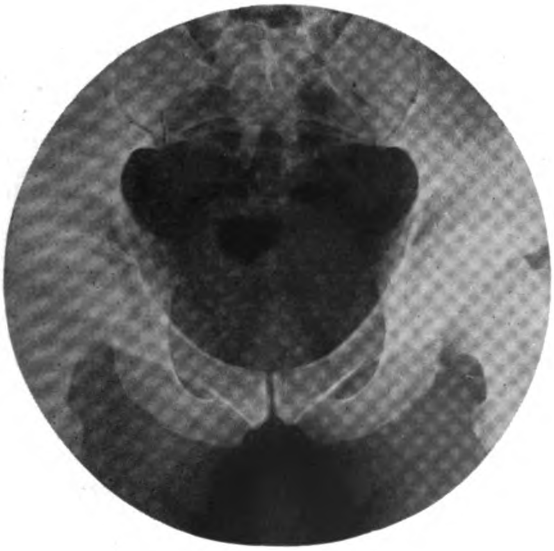


FIG. 299b

Coccyx, Antero-Posterior

The patient is placed in the supine position with the median line of the body over the centerline of the table. The tube is angled 15 degrees toward the patient's feet and the central ray is directed to a point on the median line halfway between the superior margin of the pubic symphysis and a line drawn through the anterior superior iliac spines. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—22 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 54 kilovolts peak

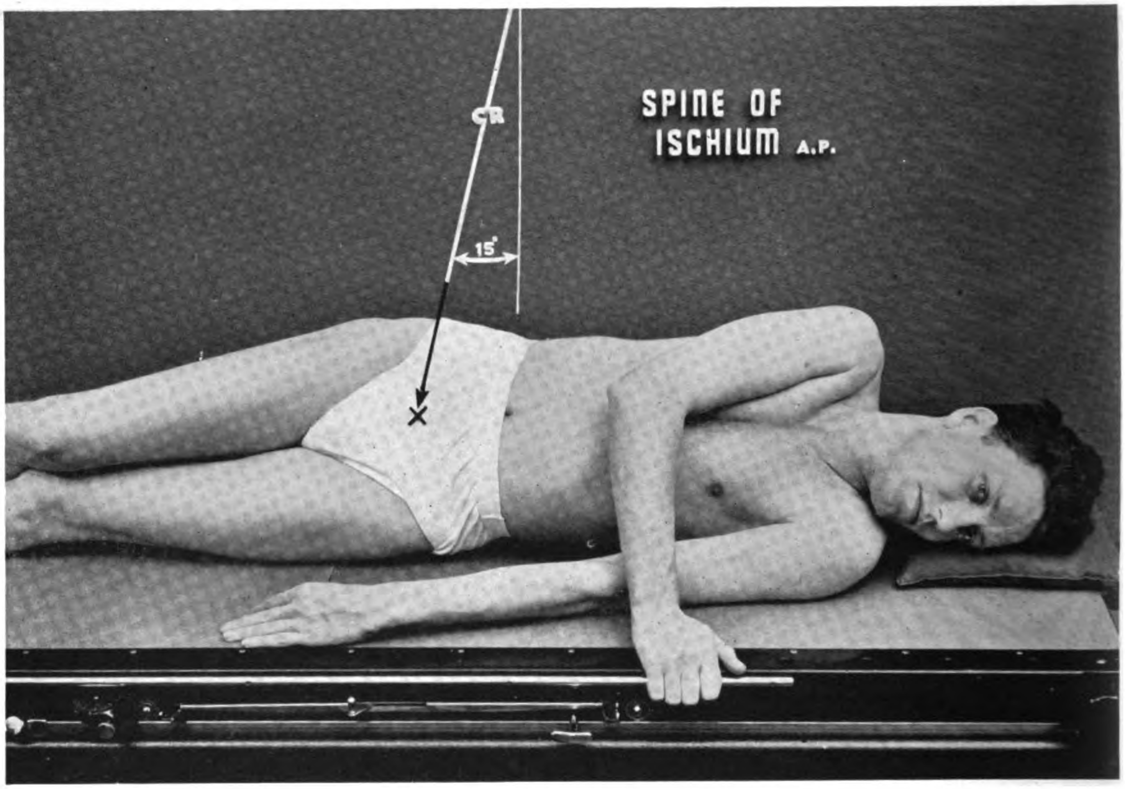


Fig. 300a

Spine of Ischium, Antero-Posterior

For the right spine of the ischium, the patient is placed in the supine position and rotated toward the left side until the body is in the semilateral position. The patient may maintain this position by flexing the upper knee and resting the foot against sandbags or the compression device. The upper arm is brought forward with the hand holding the side of the table. The median line of the body is placed over the centerline of the table. The tube is tilted 15 degrees toward the patient's feet with the central ray directed to a point on the median line halfway between the superior margin of the pubic symphysis and the level of the anterior superior iliac spines. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—16 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens

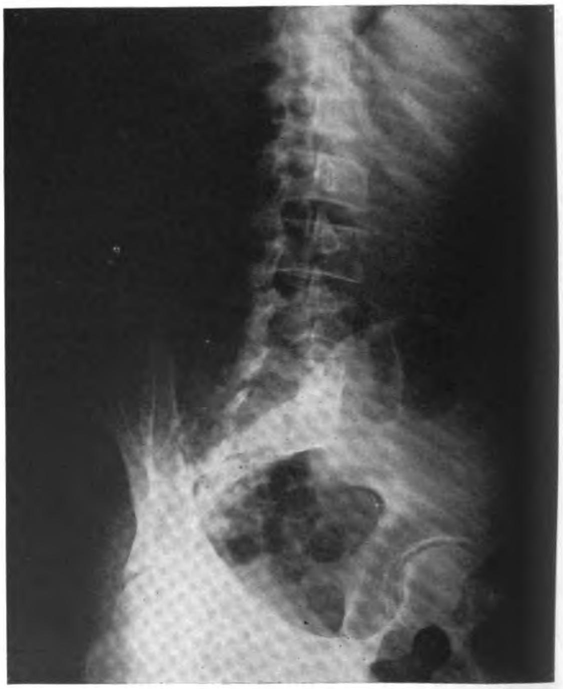


Fig. 300b

- A cone is recommended for this part
- **Suggested starting technic:**

With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 52 kilovolts peak

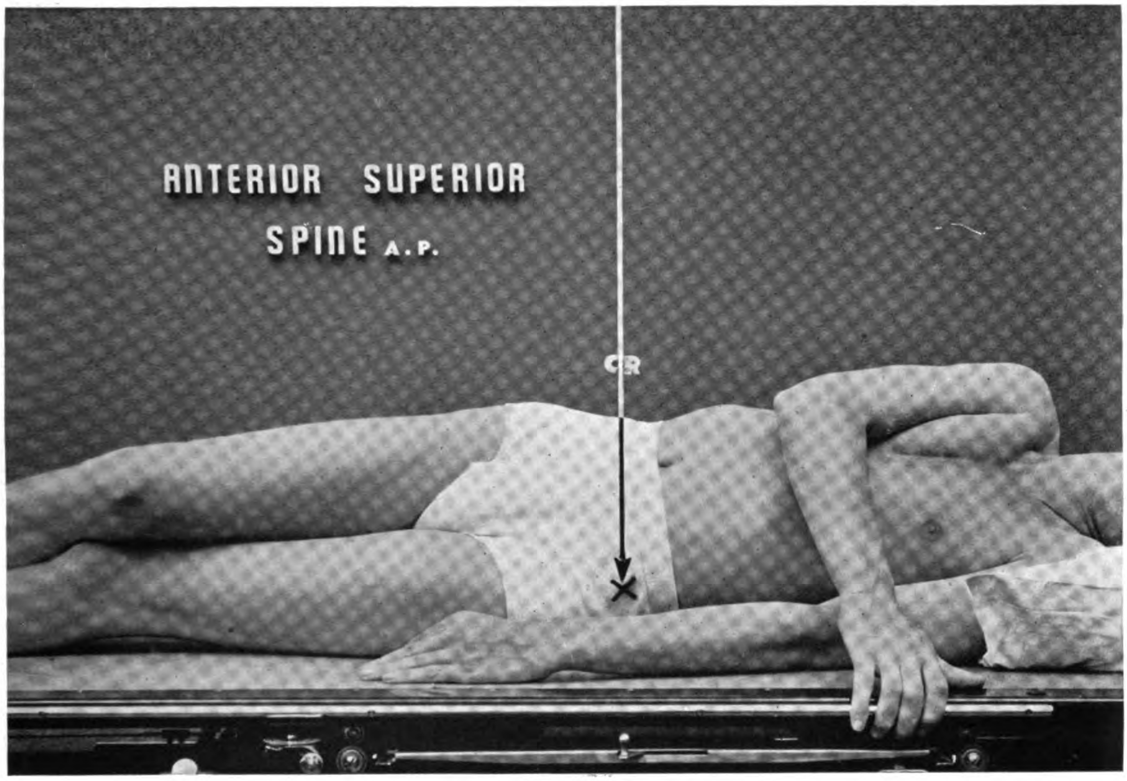


FIG. 301a

Anterior Superior Iliac Spine, Antero-Posterior

For the right anterior superior iliac spine, the patient is placed in the supine position and rotated toward the left side until the body is in the semi-lateral position. The patient may maintain this position by flexing the upper knee and resting the foot against sandbags or the compression device. The upper arm is brought forward with the hand holding the side of the table. After rotating the patient, the anterior superior spine nearer the film is placed over the center-line of the table. From the side of the table the film is centered to the anterior superior iliac spine. The central ray is directed to the center of the film.

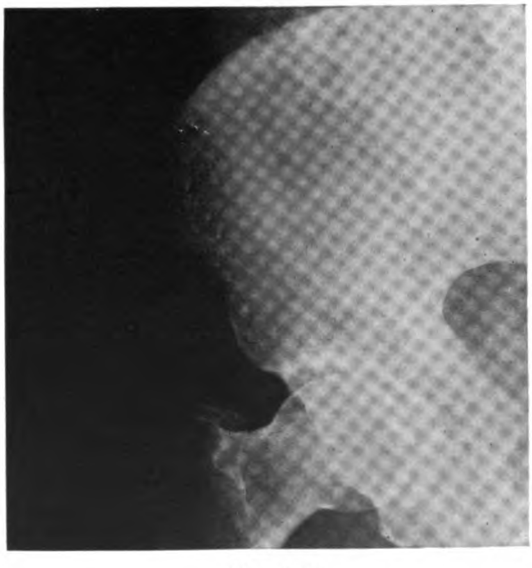


FIG. 301b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—24 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 62 kilovolts peak

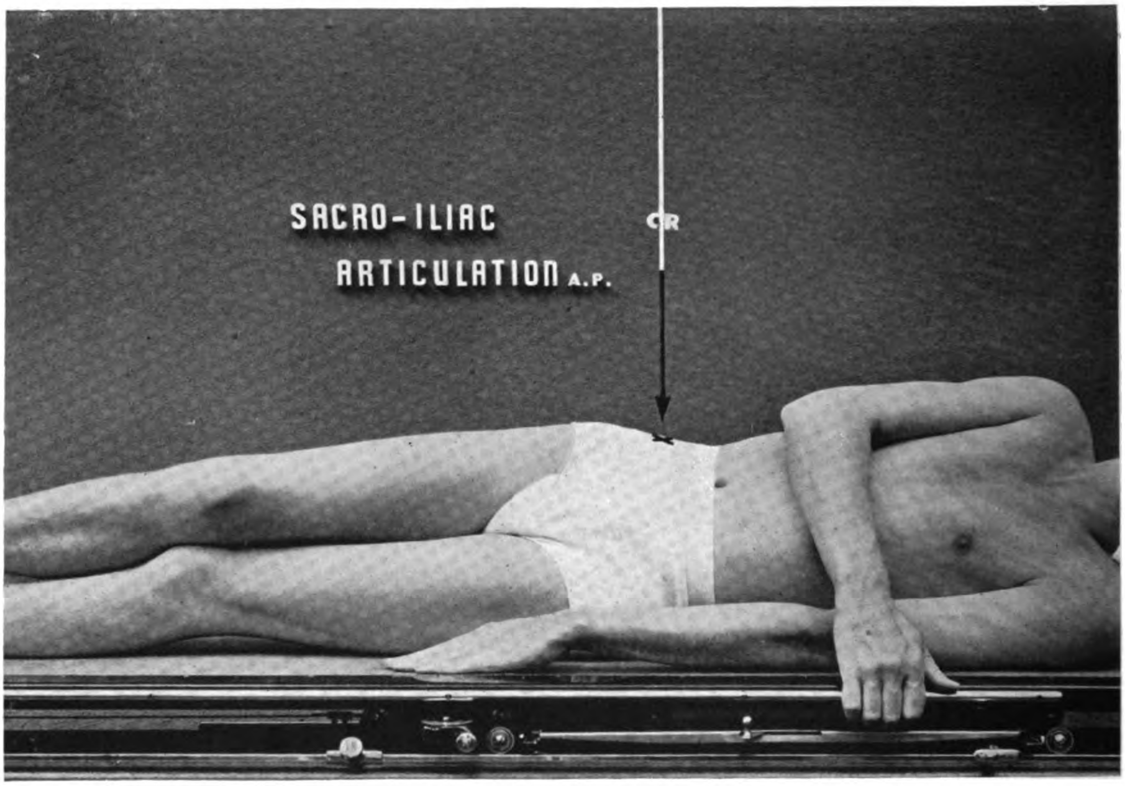


FIG. 302a

Sacro-Iliac Articulation, Antero-Posterior

For the right sacro-iliac joint, the patient is placed in the supine position and rotated toward the left side until the body is in the semi-lateral position. The patient may maintain this position by flexing the upper knee and resting the foot against sandbags or the compression device. The upper arm is brought forward with the hand holding the side of the table. The anterior superior iliac spine of the side of the body that is raised from the table top is placed over the centerline of the table. From the side of the table the film is centered to a line drawn through the anterior superior iliac spines. The central ray is directed to the center of the film.

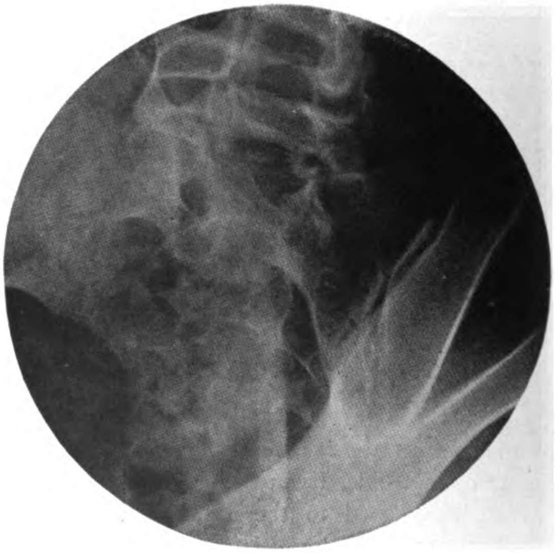


FIG. 302b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—24 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- **Suggested starting technic:**

  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 70 kilovolts peak

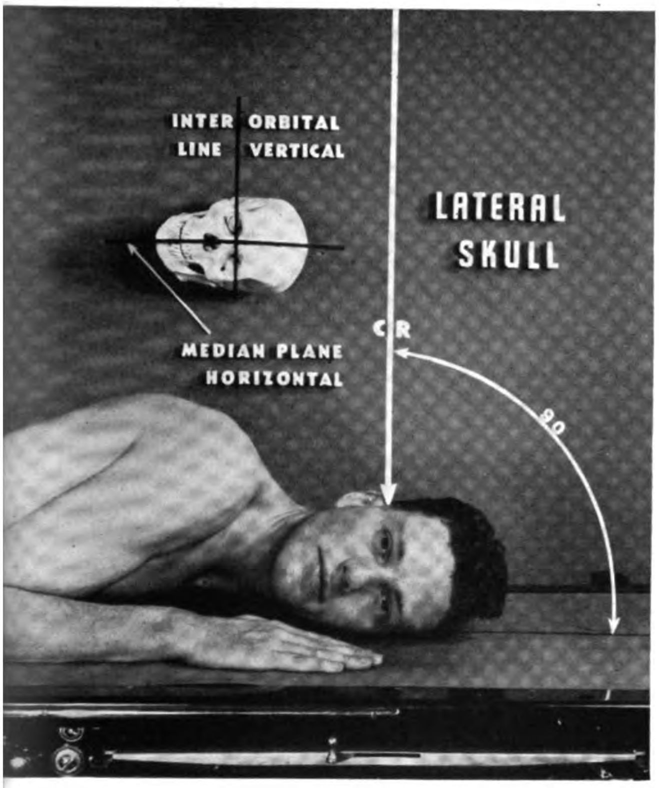


FIG. 303a

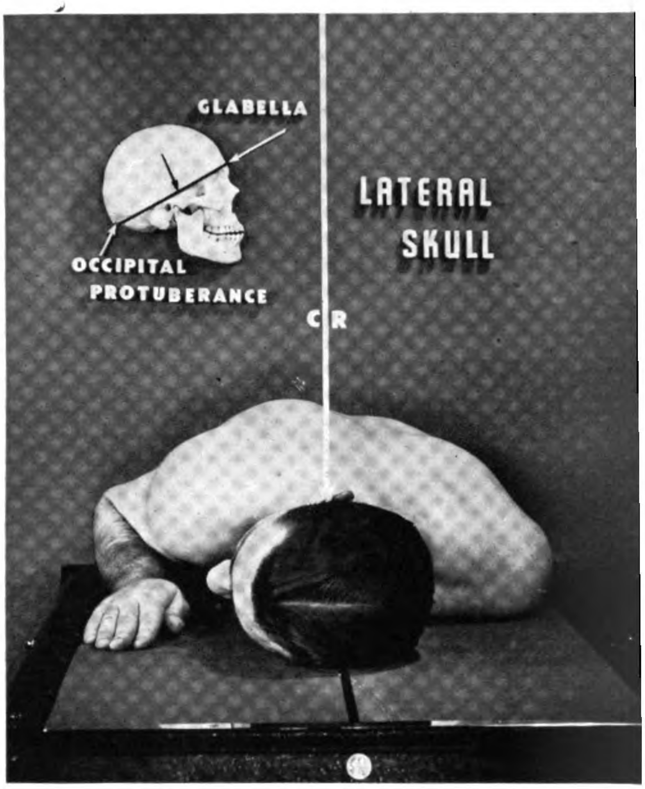


FIG. 303b

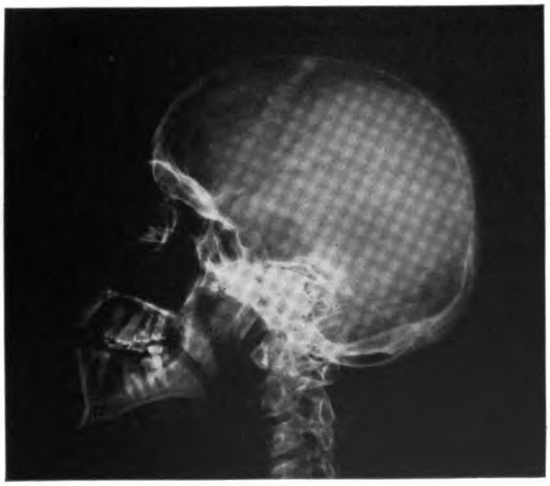


FIG. 303c

Skull, Lateral

The patient is placed in the prone position with the head turned to one side, facing the front of the table. One arm is extended along the side of the body while the opposite arm, next to the front of the table, is flexed and used to support part of the body weight. The midpoint between the glabella and the occipital protuberance is placed over the centerline of the table and from the side of the table the film is centered to the interorbital line. The median plane must be horizontal and the interorbital line vertical. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—16 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—10 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 56-kilovolts peak

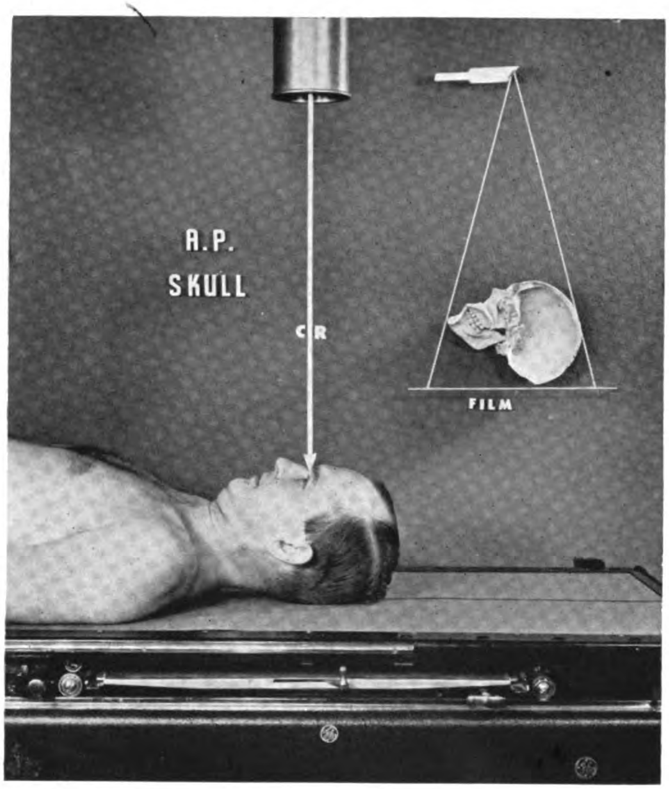


FIG. 304a

Skull, Antero-Posterior

The patient is placed on the table in the supine position with the median line over the centerline of the table. The chin is depressed until the line between the outer canthus of the eye and the external auditory meatus is vertical to the table top. From the side of the table the film is centered to the interorbital line and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—19 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 54 kilovolts peak

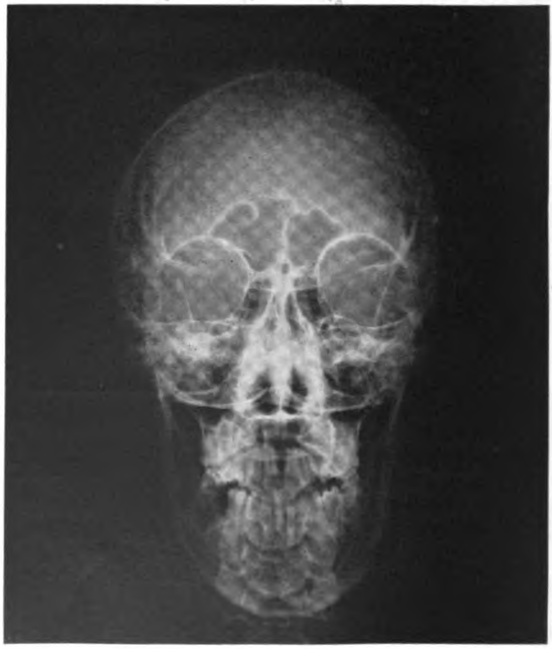


FIG. 304b

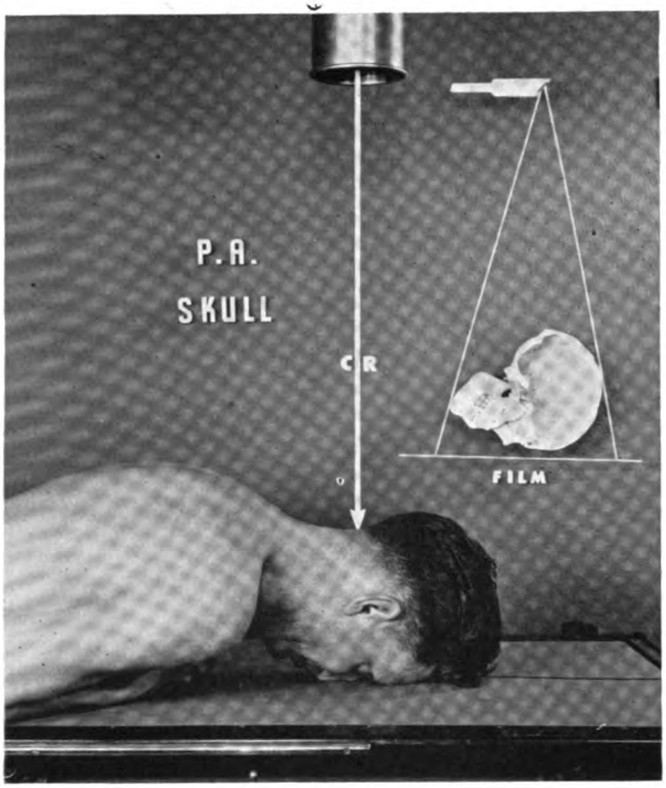


Fig. 305a

Skull, Postero-Anterior

The patient is placed on the table in the prone position with the hands folded under the chest, and with the median line over the centerline of the table. The head rests on the forehead and nose with the line between the outer canthus of the eye and the external auditory meatus at right angles to the table top. From the side of the table the film is centered to the outer canthus of the eye. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—19 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 54 kilovolts peak

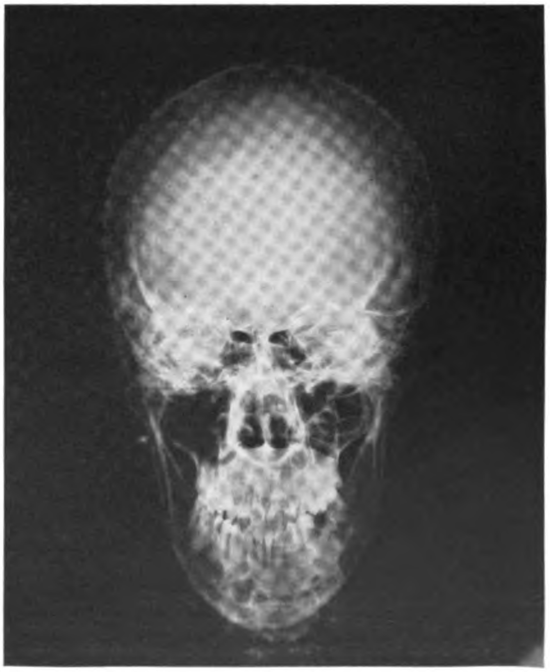


Fig. 305b

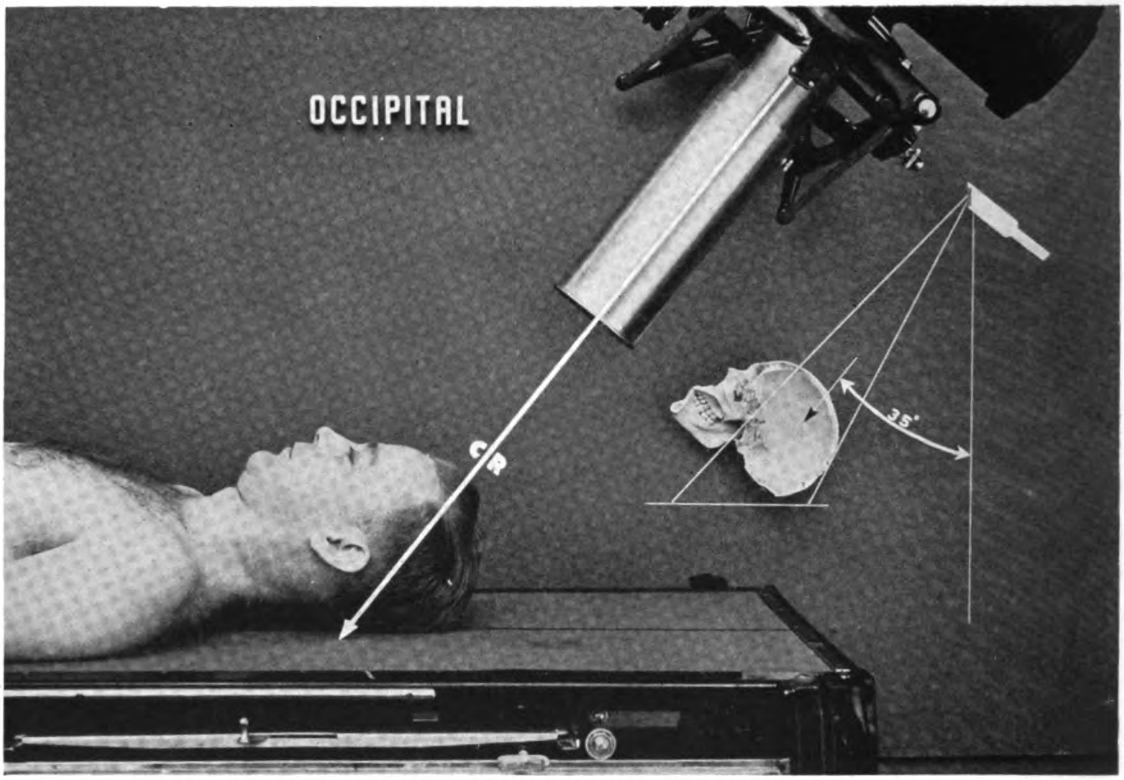


FIG. 306a

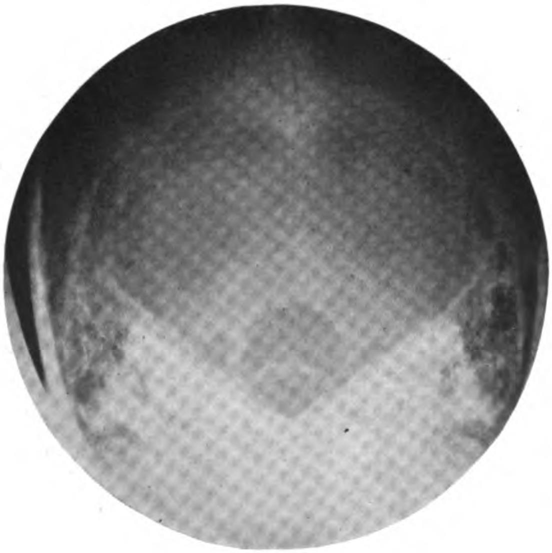


FIG. 306b

Occipital Bone, Antero-Posterior

The patient is placed in the supine position with the arms at the sides, and with the median line over the centerline of the table. The chin is depressed as far as the condition of the patient will permit. From the side of the table the film is centered to the occipital protuberance. The tube is tilted approximately 35 degrees toward the patient's feet and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—21 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 58 kilovolts peak

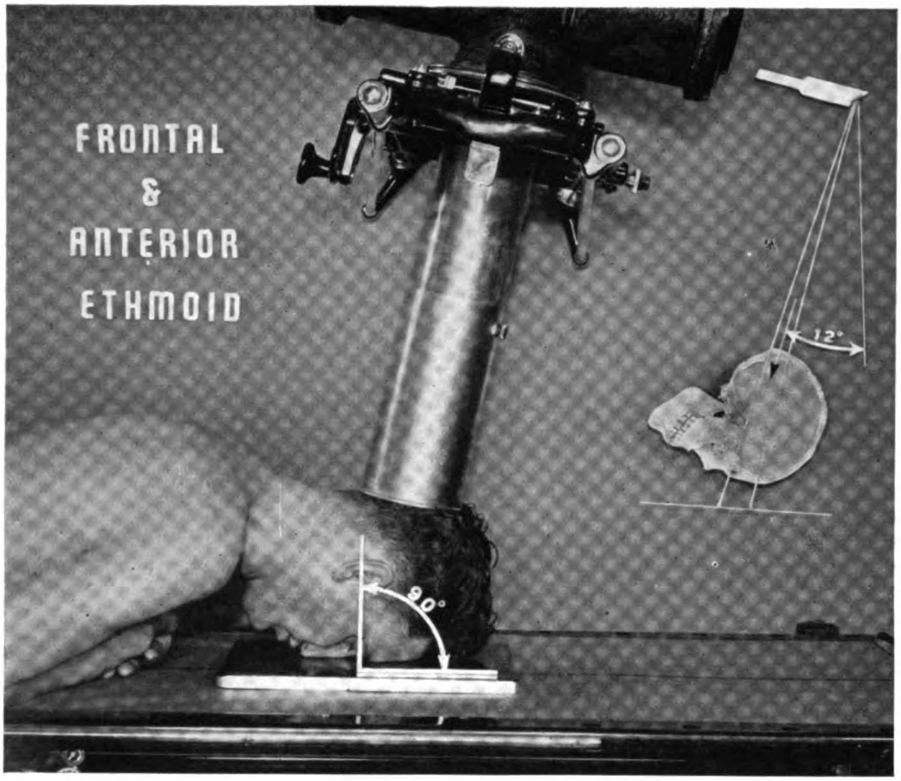


Fig. 307a

Frontal and Anterior Ethmoid Sinuses, Postero-Anterior

The patient is placed in the prone position with the hands under the chest and the forearms resting on the table. The median plane of the head must be over and perpendicular to the centerline of the film. The central point between the eyebrows is placed over the center of the film. The tube is tilted approximately 12 degrees toward the patient's feet and the cone is brought down until it rests on the patient's head. This immobilizes the head and automatically centers the central ray to the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 56 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-second, 30-inch distance, 58 kilovolts peak

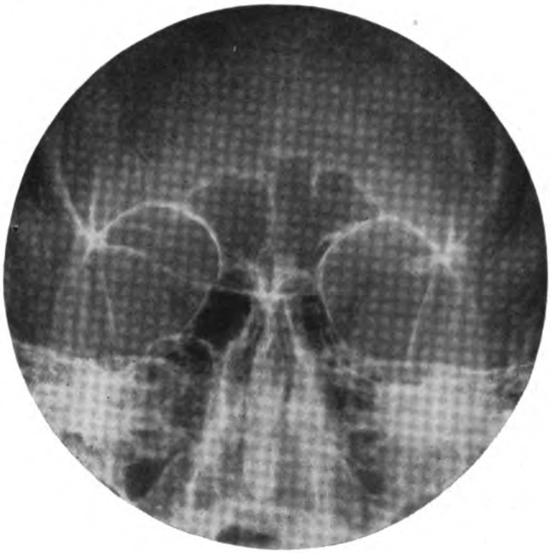


Fig. 307b

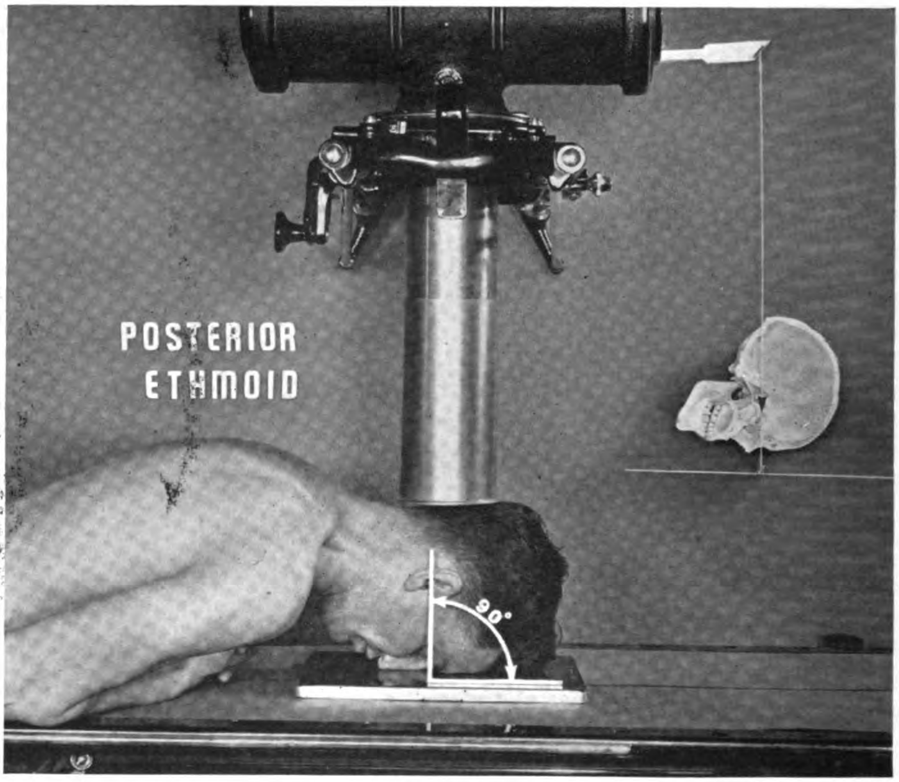


FIG. 308a

Posterior Ethmoid Sinus, Postero-Anterior

The patient is placed in the prone position with the hands under the chest and the forearms resting on the table. The median plane of the head must be over and perpendicular to the centerline of the film. The central point between the eyebrows is placed over the center of the film. The head is tilted until the line between the external auditory meatus and the outer canthus of the eye is at right angles to the film. The cone rests lightly on the patient's head and is centered to the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**

  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 48 kilovolts peak

  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 50 kilovolts peak

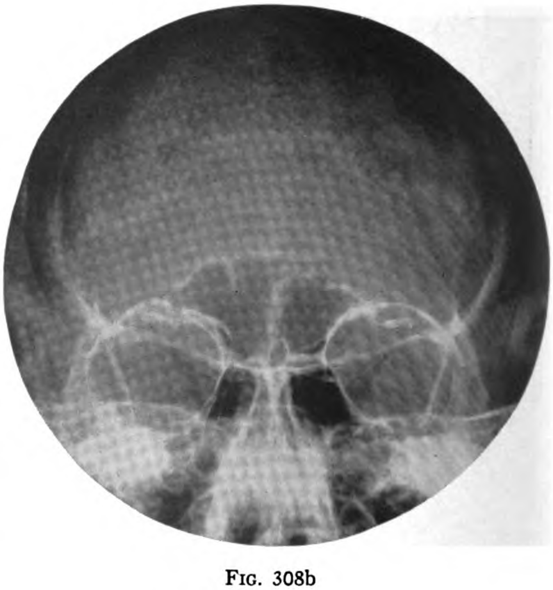


FIG. 308b

Maxillary Sinus, Postero-Anterior

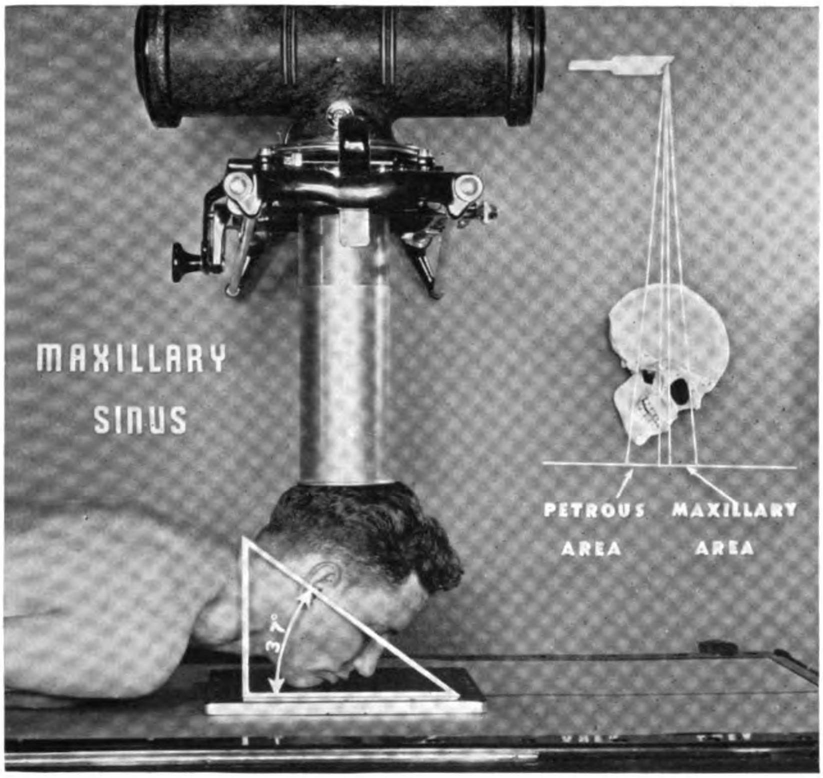


Fig. 309a

The patient is placed in the prone position with the arms at the sides. With the full weight of the head resting on the chin, the head is tilted until a line between the external auditory meatus and and the outer canthus of the eye forms an angle of 37 degrees with the table top. With the head in this position, the image of the petrous portion of the temporal bone is below that of the maxillary sinuses. The film is centered to the junction of the nose and upper lip. The median plane must be over and perpendicular to the centerline of the film. The cone is brought in contact with the patient's head which immobilizes the part and automatically directs the central ray to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 60 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 62 kilovolts peak

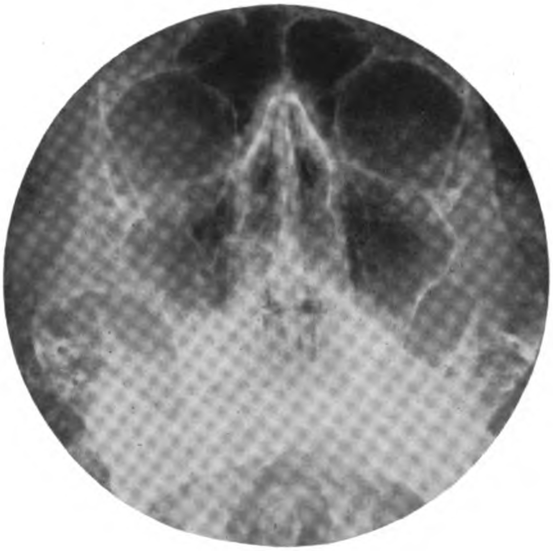


Fig. 309b

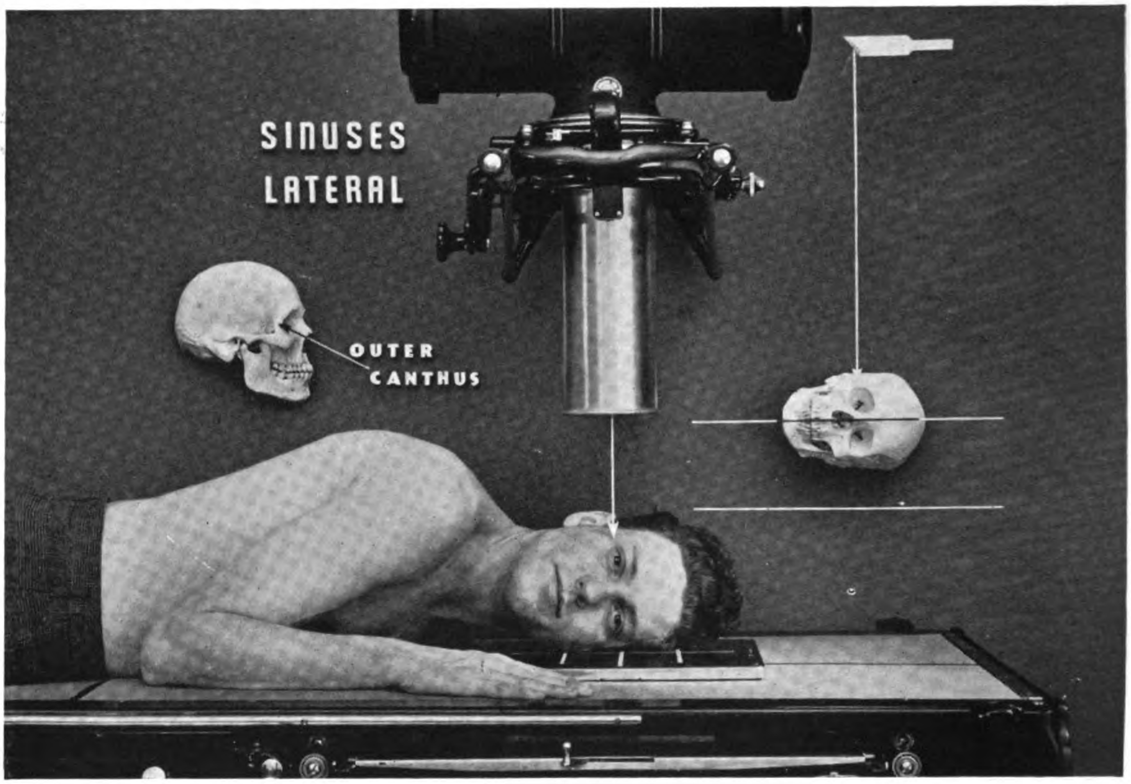


FIG. 310a

Sinuses, Lateral

The patient is placed in the prone position with the head turned to one side facing the front of the table. One arm is extended along the side of the body, while the arm at the front of the table is flexed and used for support. The outer canthus of the eye is placed over the center of the film. The median plane must be horizontal. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—13 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—10 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**

With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 36-inch distance, 48 kilovolts peak

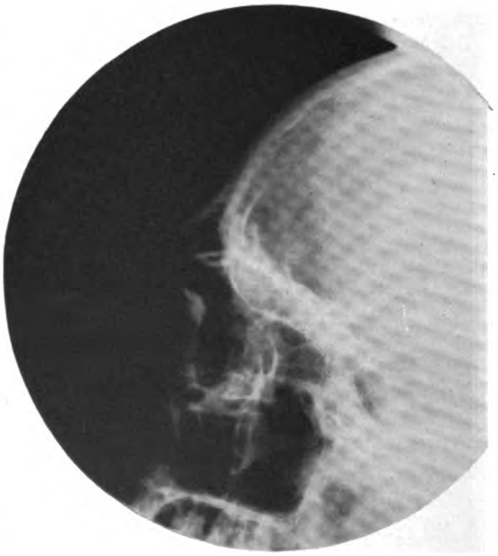


FIG. 310b

With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 36-inch distance, 50 kilovolts peak

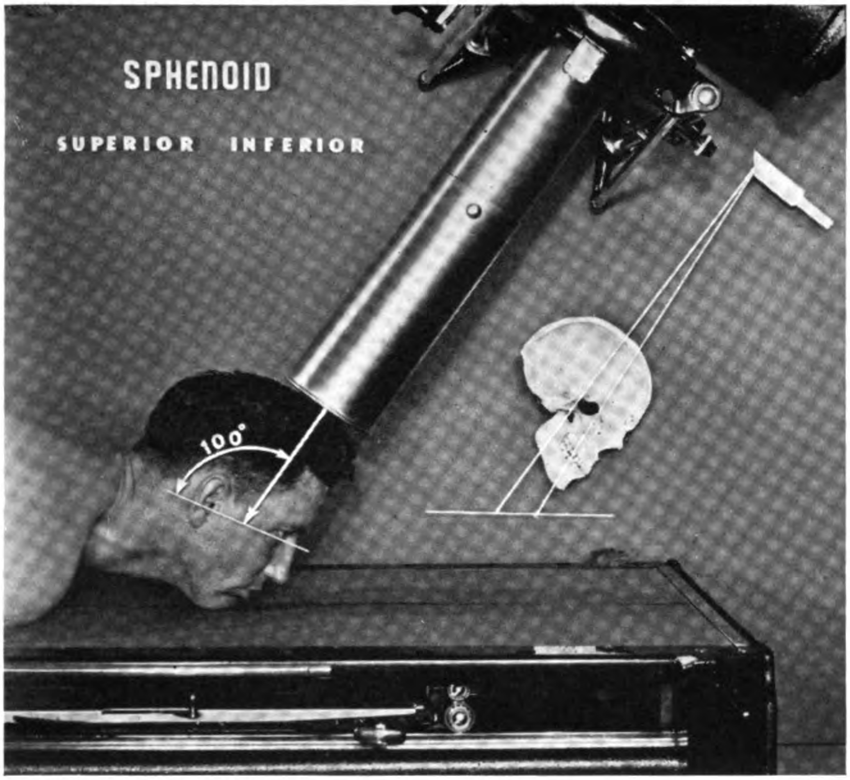


FIG. 311a

Sphenoid Sinus, Supero-Inferior

The patient is placed on the table in the prone position with the arms at the sides and with the head resting on the chin. The median plane of the head must be over and perpendicular to the centerline of the cassette or table. The chin is extended as far forward as possible. The tube is tilted toward the patient's feet until the central ray bisects a line between the outer canthus of the eye and the external auditory meatus, at an angle of 100 degrees. The film is centered to the central ray.

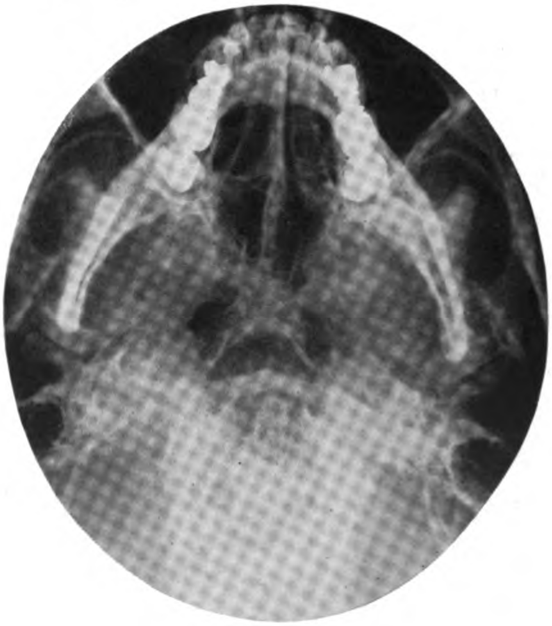


FIG. 311b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—24 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 30-inch distance, 62 kilovolts peak

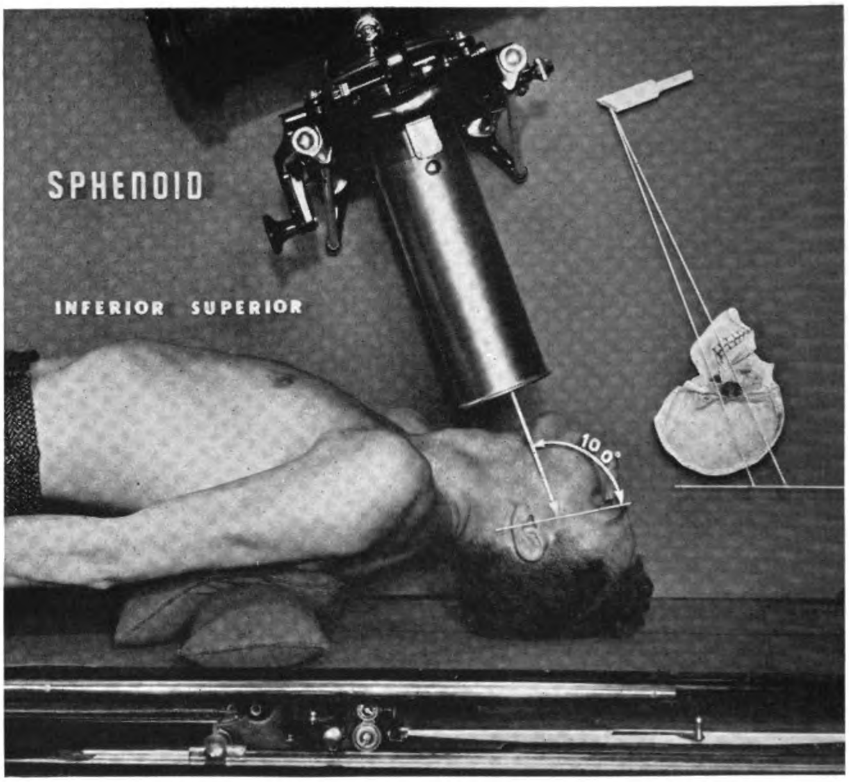


FIG. 312a

Sphenoid Sinus, Infero-Superior

The patient is placed in the supine position with the shoulders elevated by sandbags or a pillow so that the top of the patient's head rests on the cassette or table top. The median plane of the head must be over and perpendicular to the centerline of the film. The tube is tilted toward the patient's head until the central ray bisects a line between the outer canthus of the eye and the external auditory meatus at an angle of 100 degrees. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—24 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak

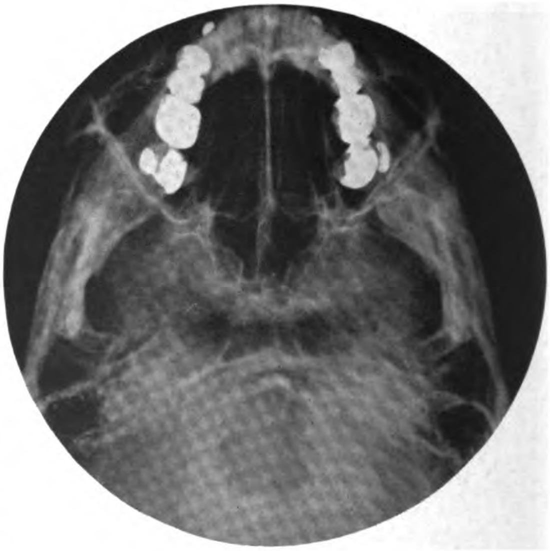


FIG. 312b

With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 30-inch distance, 62 kilovolts peak

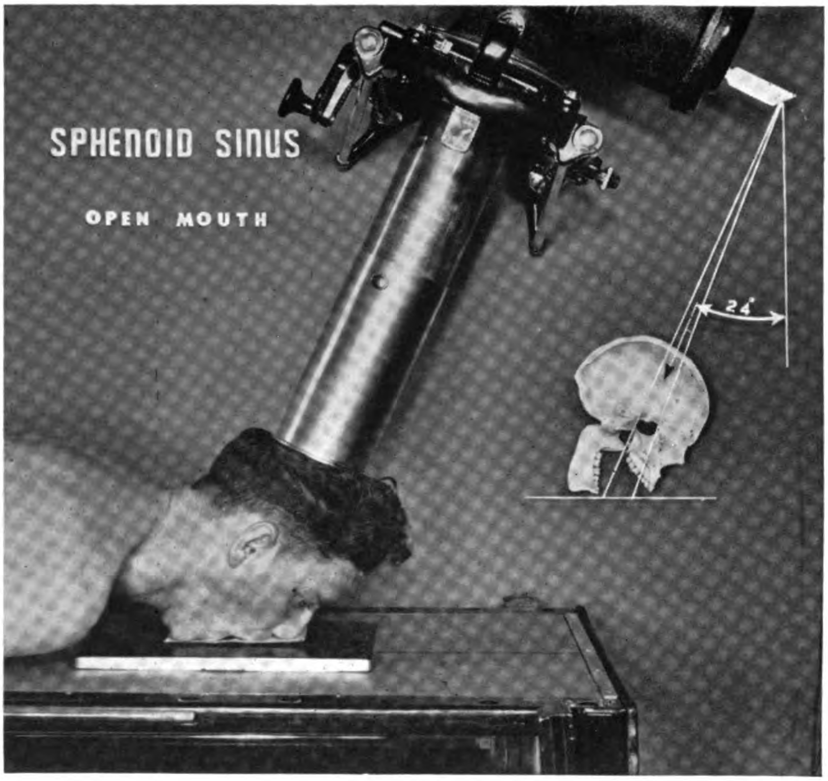


FIG. 313a

Sphenoid Sinus, Postero-Anterior, Open Mouth

The patient is placed in the prone position with the arms at the sides and with the head resting on the open mouth. The median plane must be over and perpendicular to the centerline of the film. From the side, the crossline of the film is centered to the junction of the upper and lower lips. The tube is tilted 24 degrees toward the patient's feet and the cone is brought down in contact with the patient's head. This will immobilize the head and automatically direct the central ray to the center of the film. Just before the exposure is made, the patient is instructed to open the mouth as wide as possible.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—21 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure

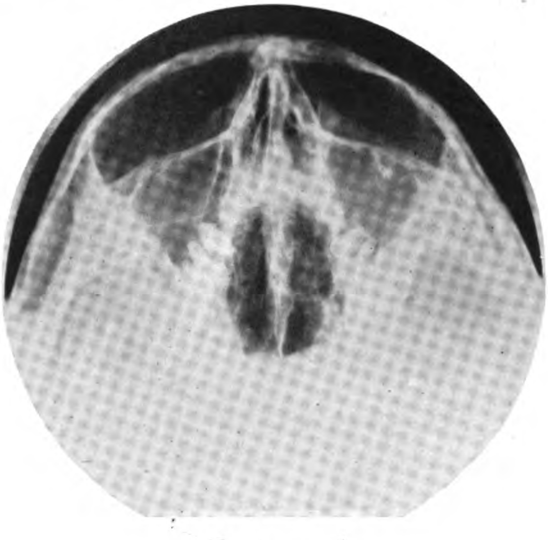


FIG. 313b

- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 56 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 30 inch distance, 58 kilovolts peak

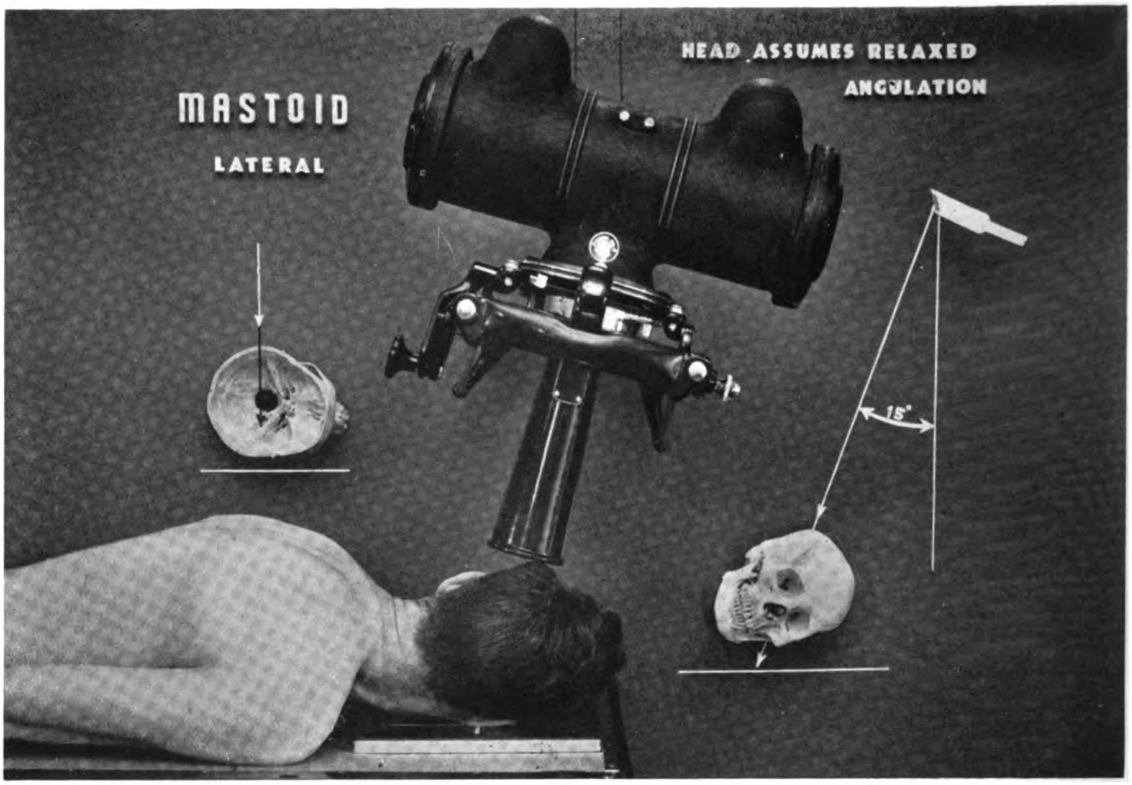


FIG. 314a

Mastoid, Lateral

The right and left mastoids are usually radiographed on the same film for comparison. The cassette is placed crosswise and the opposite half of the film need not be covered with a lead mask if a 3-inch cone is used.

The patient is placed in the prone position, head turned to one side, the arms extended along the body. If the right mastoiod is to be radiographed first, the right external auditory meatus is placed over the center of one half of the film. The head is allowed to assume a relaxed position. The tube is tilted 15 degrees toward the patient's feet, the central ray is directed to the center of one half of the film. To radiograph the other mastoid, the same procedure is used on the other half of the film.

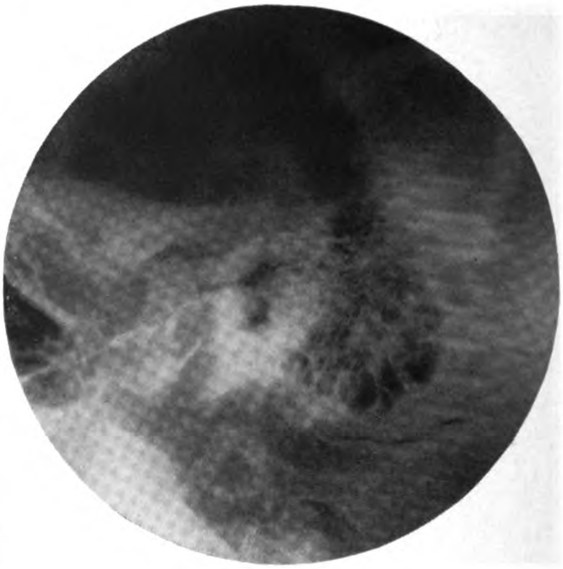


FIG. 314b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—8 kilovolts peak with Parspeed screens
- A 3-inch cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 50 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 54 kilovolts peak

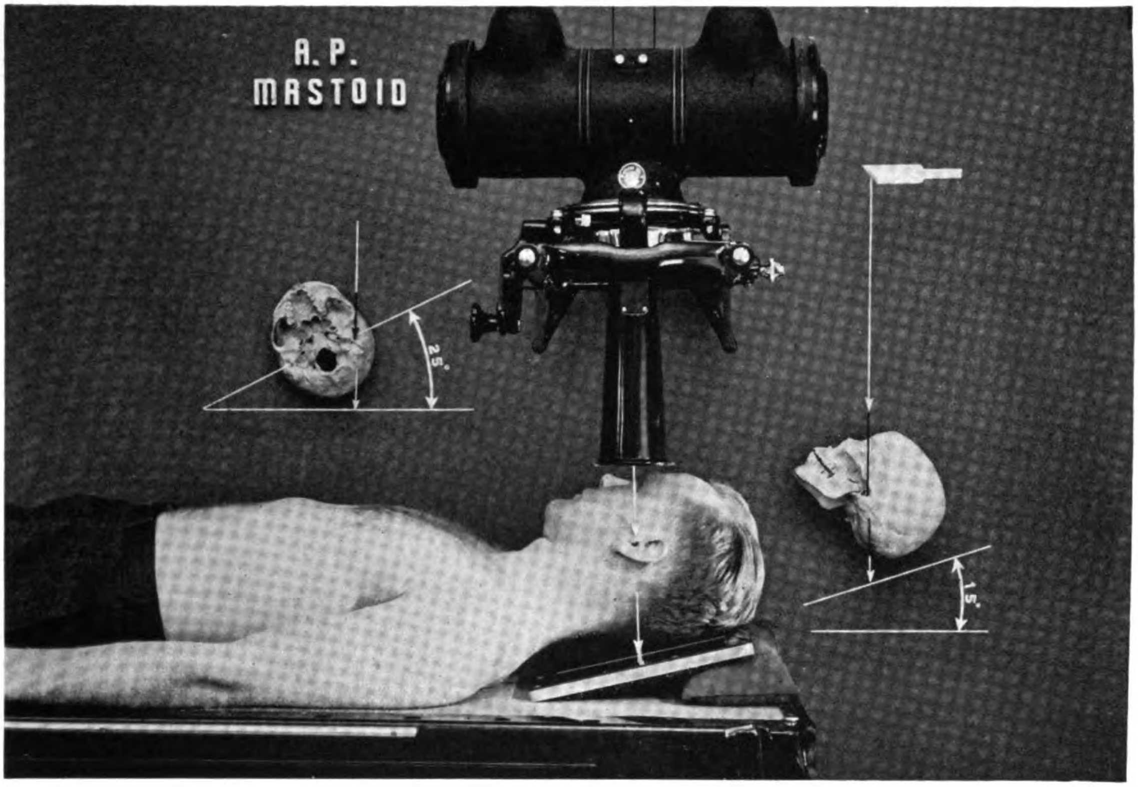


FIG. 315a

Mastoid, Antero-Posterior

The right and left mastoids are usually radiographed on the same film. The cassette is used crosswise and is elevated by a sandbag, forming an angle of 15 degrees with the table top. The opposite half of the film need not be covered with a lead mask if a 3-inch cone is used.

The patient is placed in the supine position with the median line of the head over the crossline of the cassette. From the side of the table, the external auditory meatus is placed over the centerline of the cassette. If the left mastoid is to be radiographed first, the head is raised and rotated to the right approximately 25 degrees. The tube is positioned so that the central ray will be directed 2 inches from the center of the cassette on a line through the external auditory meatus. The same procedure is used for the opposite mastoid. When positioning the patient, it is important that the head be raised and rotated, not rolled.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—13 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—8 kilovolts peak with Parspeed screens
- A 3-inch cone is recommended for this part (long dental cone)
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 25 milliampere-seconds, 25-inch distance, 50 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 50 milliampere-seconds, 25 inch distance, 58 kilovolts peak

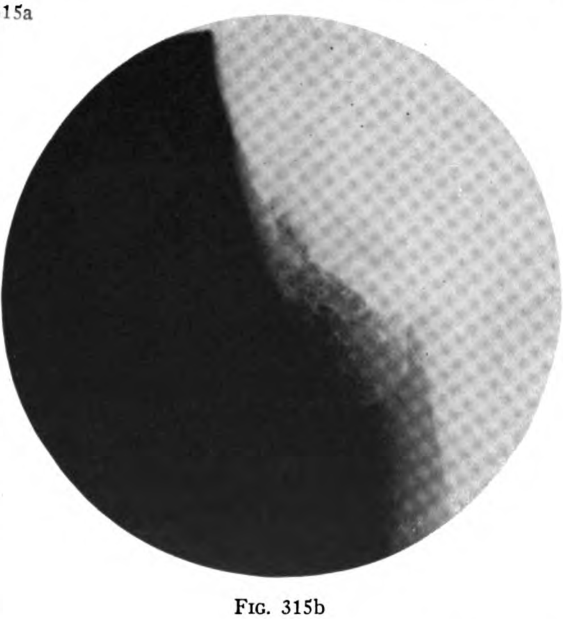


FIG. 315b

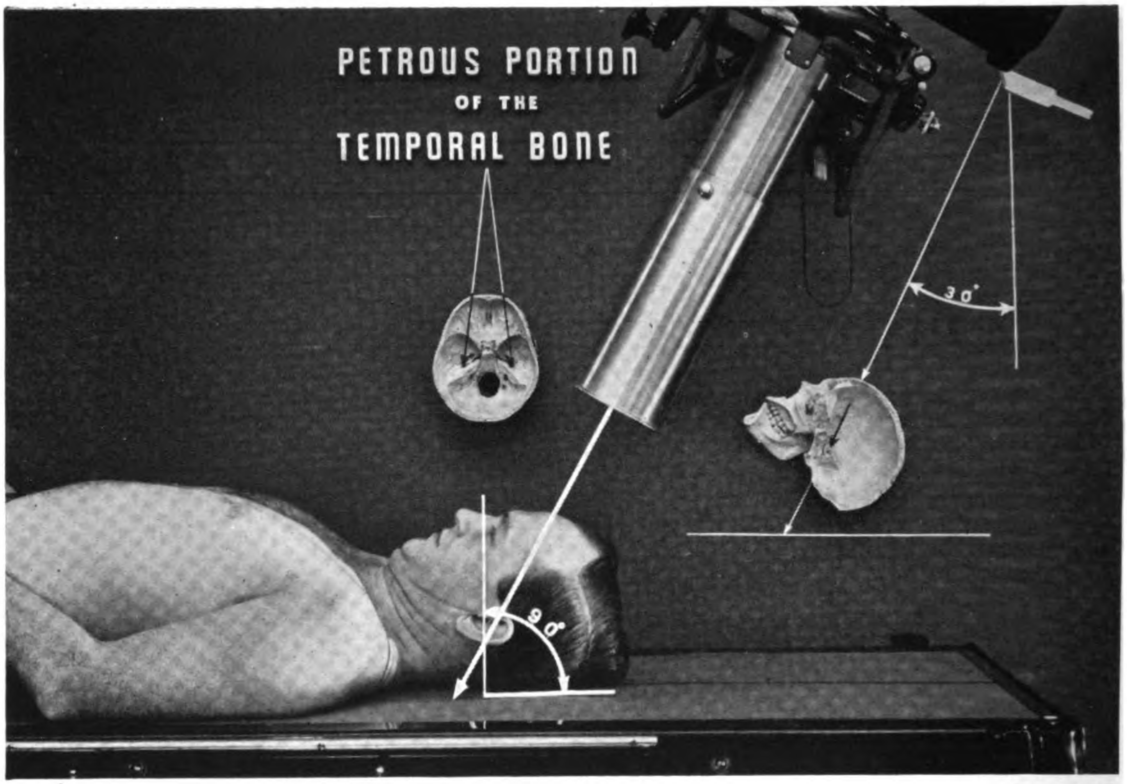


FIG. 316a

Petrous Portion of the Temporal Bone, Antero-Posterior

The patient is placed on the table in the supine position with the median line of the body over the centerline of the table. The chin is depressed until the line between the outer canthus of the eye and the external auditory meatus is at right angles to the table top. With the tube tilted 30 degrees toward the patient's feet, the central ray bisects a line through the skull connecting the external auditory meati. The film is centered to the central ray.

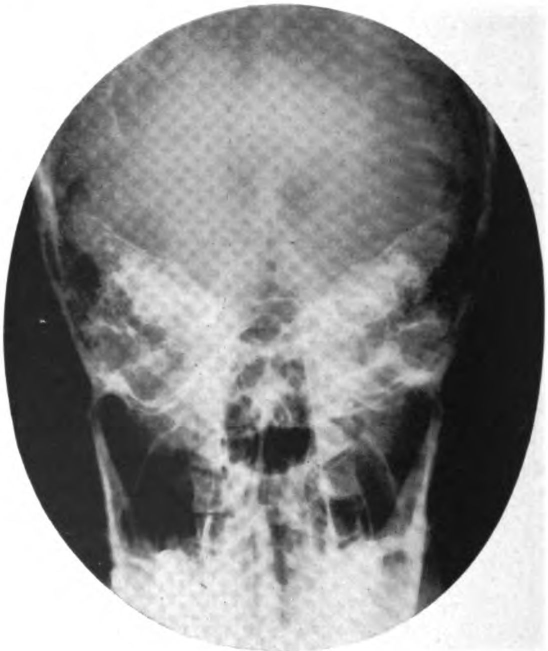


FIG. 316b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—19 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 56 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak

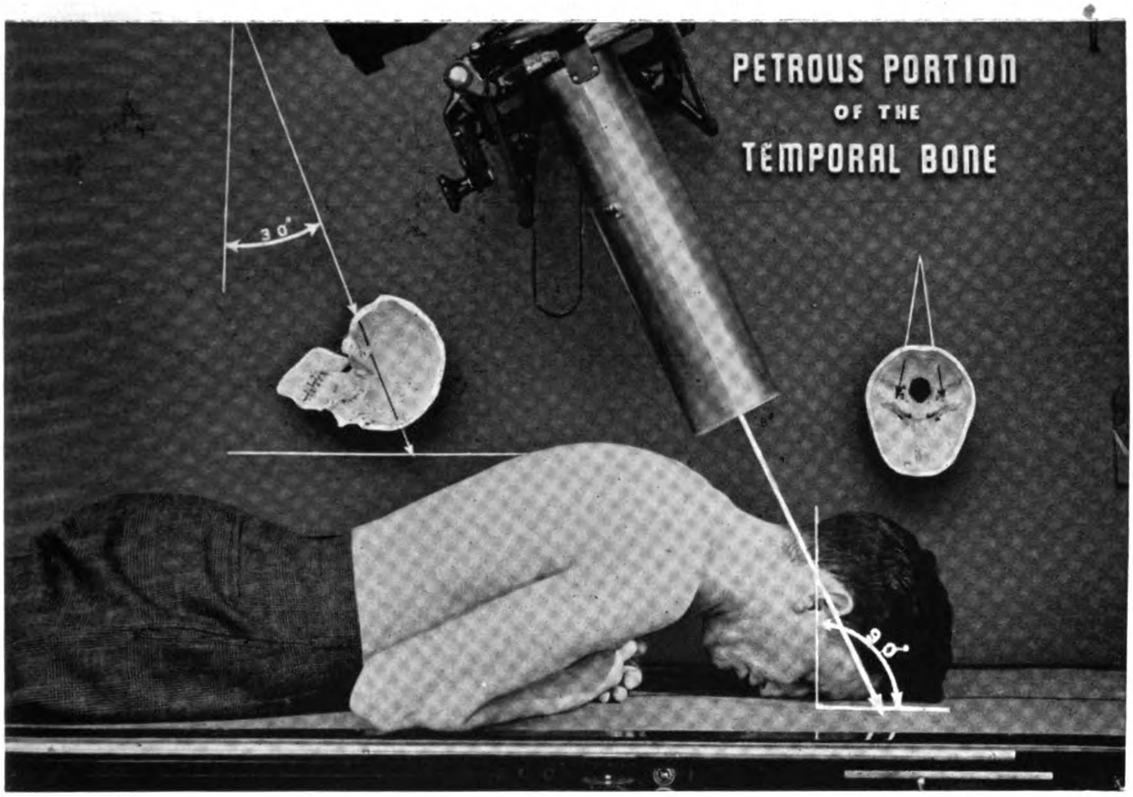


FIG. 317a

Petrous Portion of the Temporal Bone, Postero-Anterior

The patient is placed on the table in the prone position with the hands under the chest and the forearms resting on the table. The median plane of the body is placed over the centerline of the table. The head is in the nose-forehead position with the line between the outer canthus of the eye and the external auditory meatus at right angles to the table top. With the tube tilted 30 degrees toward the patient's head, the central ray bisects a line through the skull connecting the external auditory meati. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—19 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure

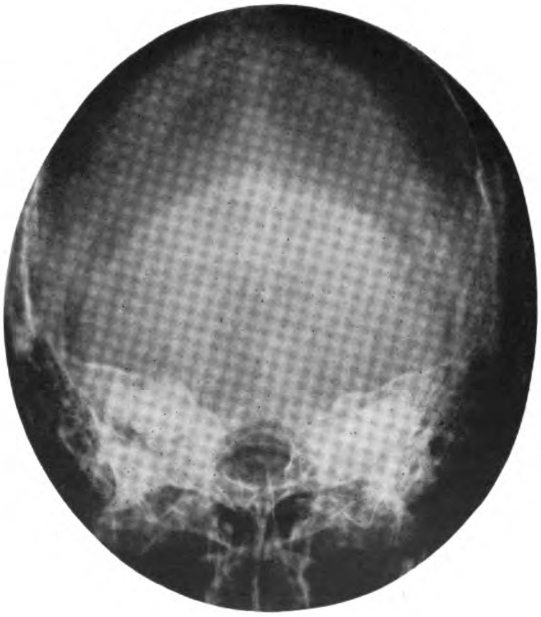


FIG. 317b

- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 56 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak

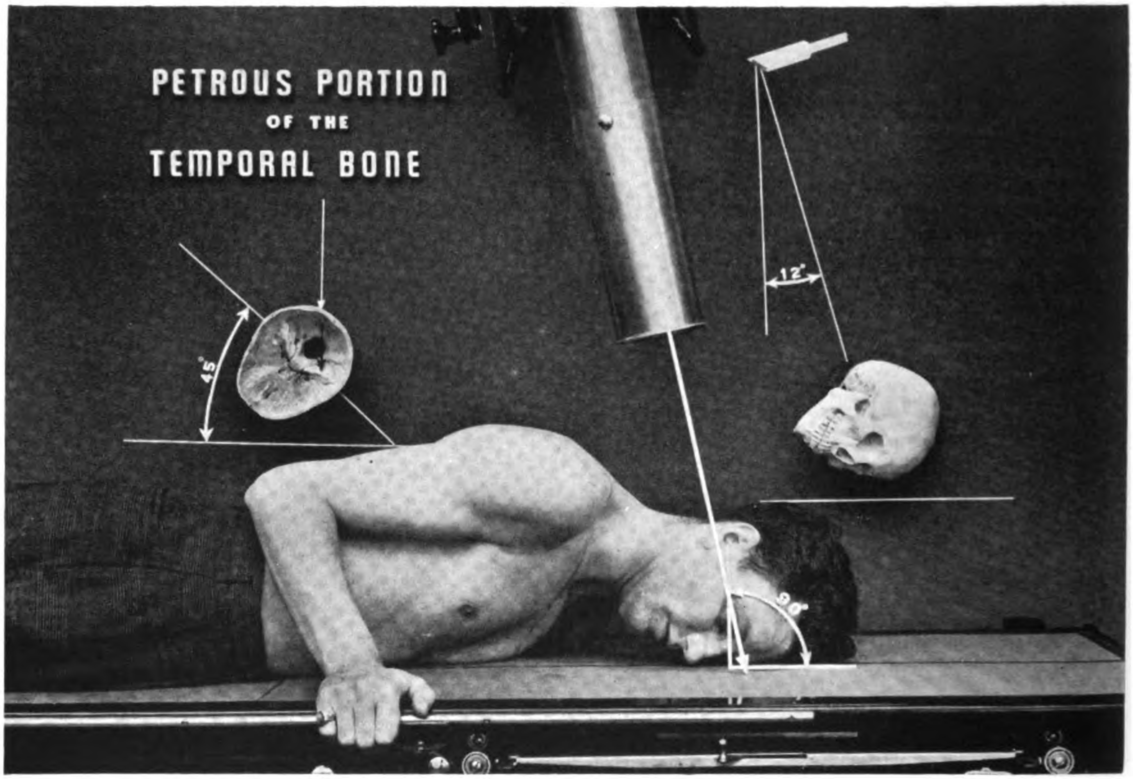


FIG. 318a

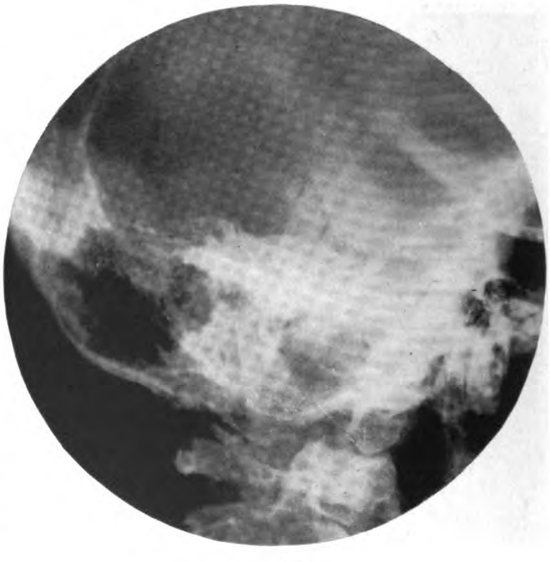


FIG. 318b

Petrous Portion of the Temporal Bone, Postero-Anterior Oblique

The patient is placed on the table in the prone position with one arm at the side and one arm used for support. The head is rotated 45 degrees, the external auditory meatus nearest the film is located over the table centerline. If the left petrous portion is desired, the left external auditory meatus is the one that is placed closer to the film and over the table centerline. A line projected through the external auditory meatus and the outer canthus of the eye is at right angles to the table top. The tube is tilted 12 degrees toward the patient's head. The central ray passes through the skull level with the outer canthus of the eye. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—19 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**

  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 56 kilovolts peak

  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak

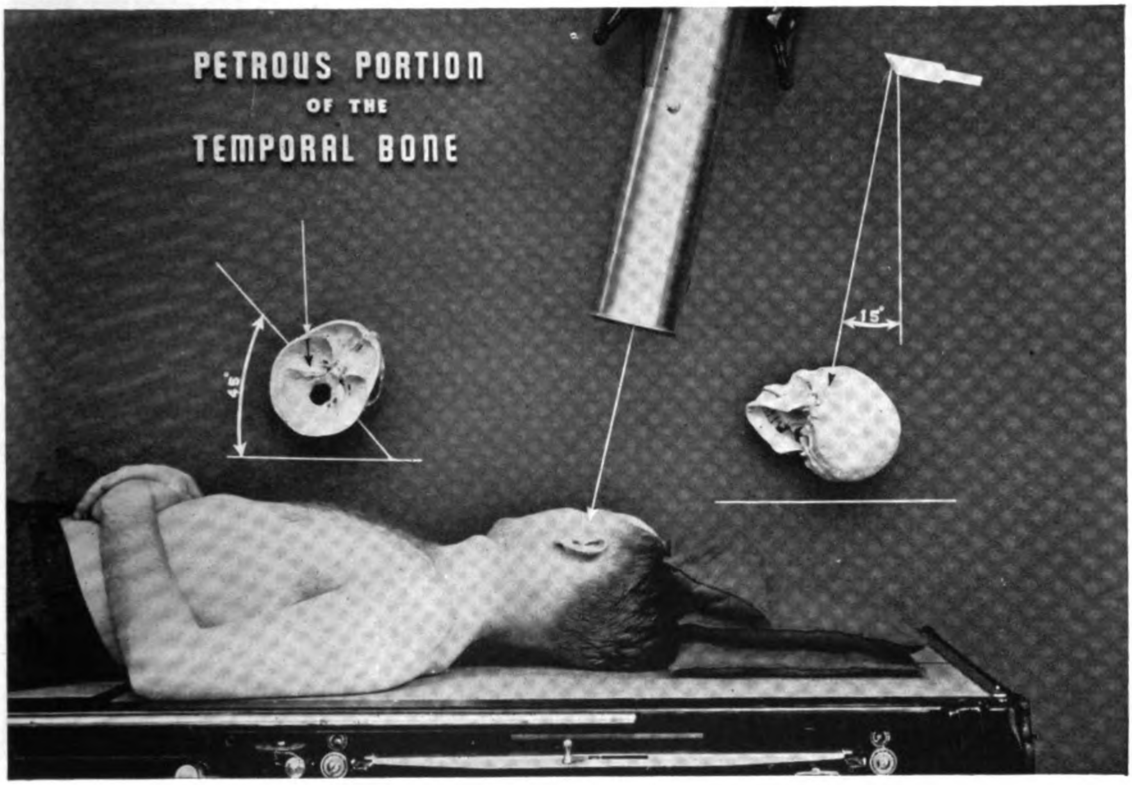


FIG. 319a

Petrous Portion of the Temporal Bone, Antero-Posterior Oblique

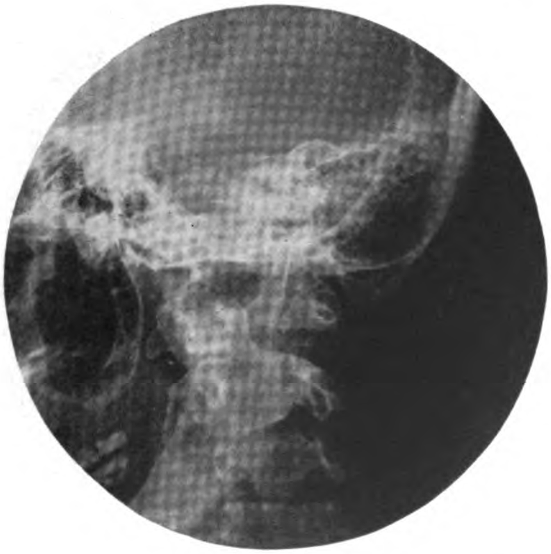


FIG. 319b

The patient is placed in the supine position with the median line of the body over the centerline of the table. If the left petrous portion is to be radiographed, the head is rotated to the right 45 degrees. The midpoint of the line between the outer canthus of the eye and the external auditory meatus is placed over the centerline of the table. The tube is tilted 15 degrees toward the patient's feet and the central ray is directed to the midpoint of the above line. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—19 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 56 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak

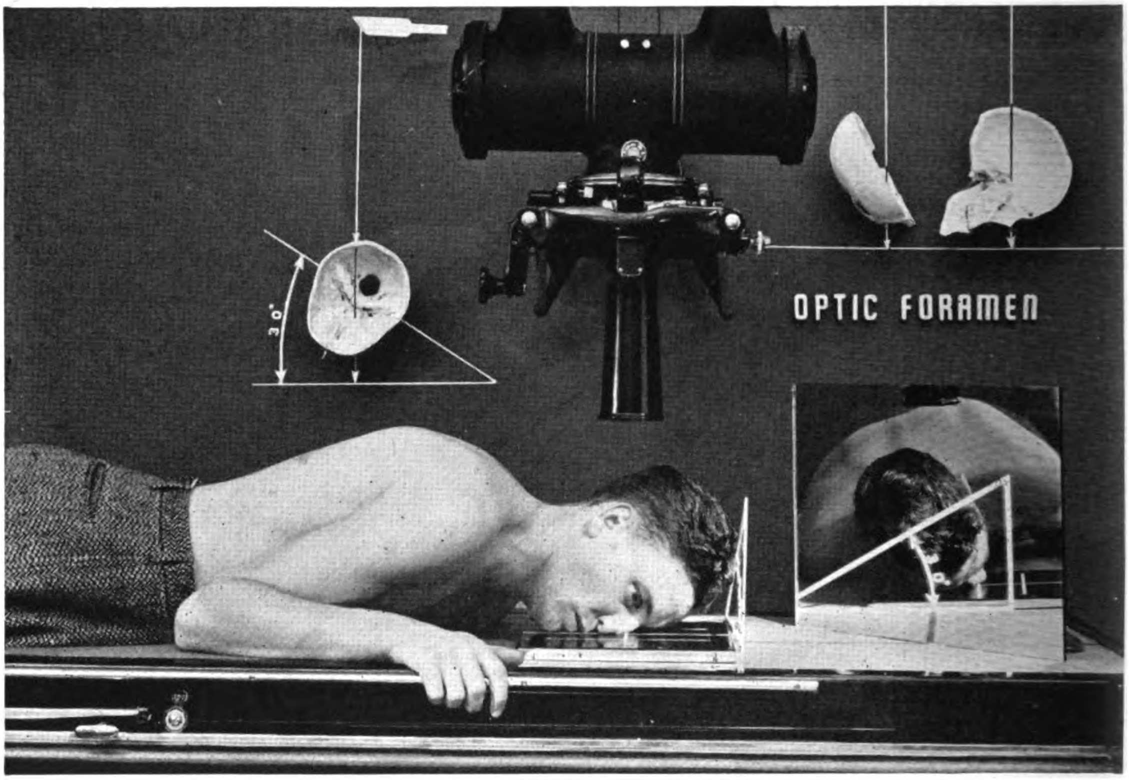


Fig. 320a

Optic Foramen, Postero-Anterior Oblique

Both foramina are usually radiographed on the same film for comparison. When a 3-inch cone is employed, it is unnecessary to use a lead mask to protect that half of the film not being exposed.

With the patient in the prone position, one arm is flexed and used for support while the opposite arm is at the side. The head is rotated 30 degrees and the center of the orbit is placed over the center of one half of the film. The zygomatic arch and the upper border of the orbit must rest firmly on the cassette. The central ray is centered to one half of the film. The same procedure is used for the opposite foramen.

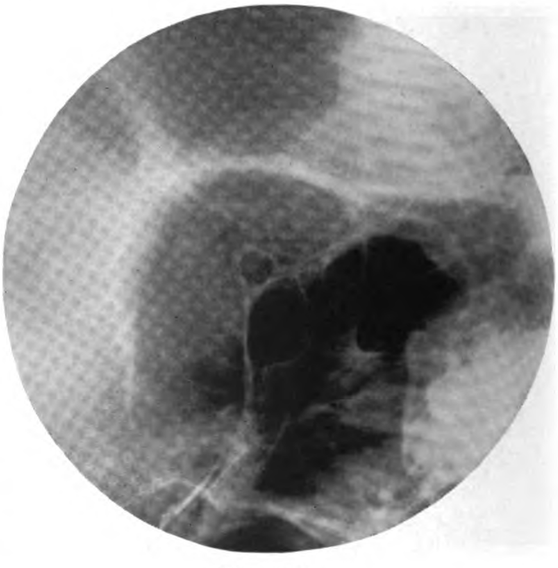


Fig. 320b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—19 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A 3-inch cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**

With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 58 kilovolts peak

With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 60 kilovolts peak

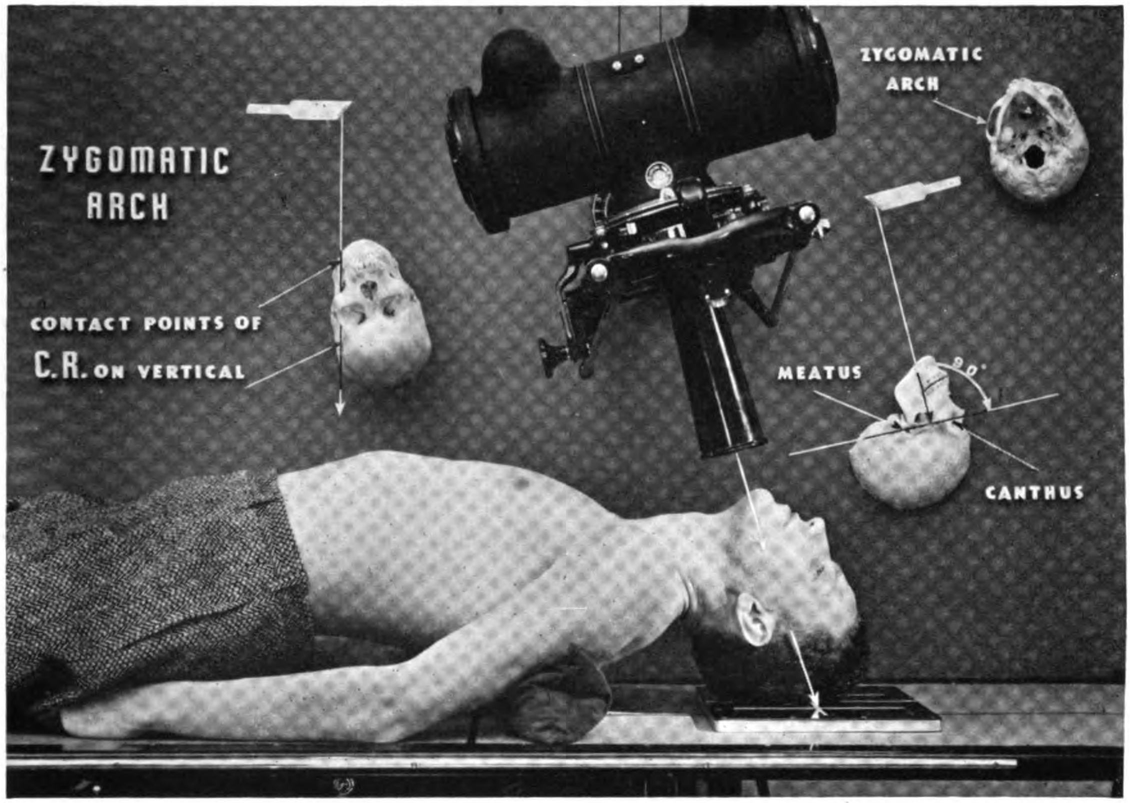


FIG. 321a

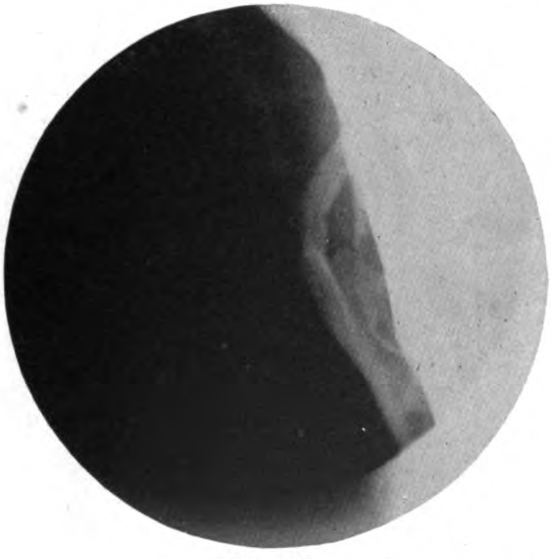


FIG. 321b

Zygomatic Arch, Infero-Superior

The patient is placed in the supine position with the shoulders elevated by sandbags so that the top of the head rests on the film holder. From the side of the table the tube is tilted until the central ray bisects at right angles a line drawn between the external auditory meatus and the outer canthus of the eye. The tilt of the tube will be determined by the plane of the above line. From the end of the table the patient's head is rotated slightly so that the central ray will contact the body of the mandible and the side of the skull as shown in the illustration. The film is centered to the central ray.

PROCEDURE

- Size of film employed—usually 8 by 10, placed crosswise to the long axis of the table
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—12 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—10 kilovolts peak with Parspeed screens
- The use of a cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 50 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 52 kilovolts peak

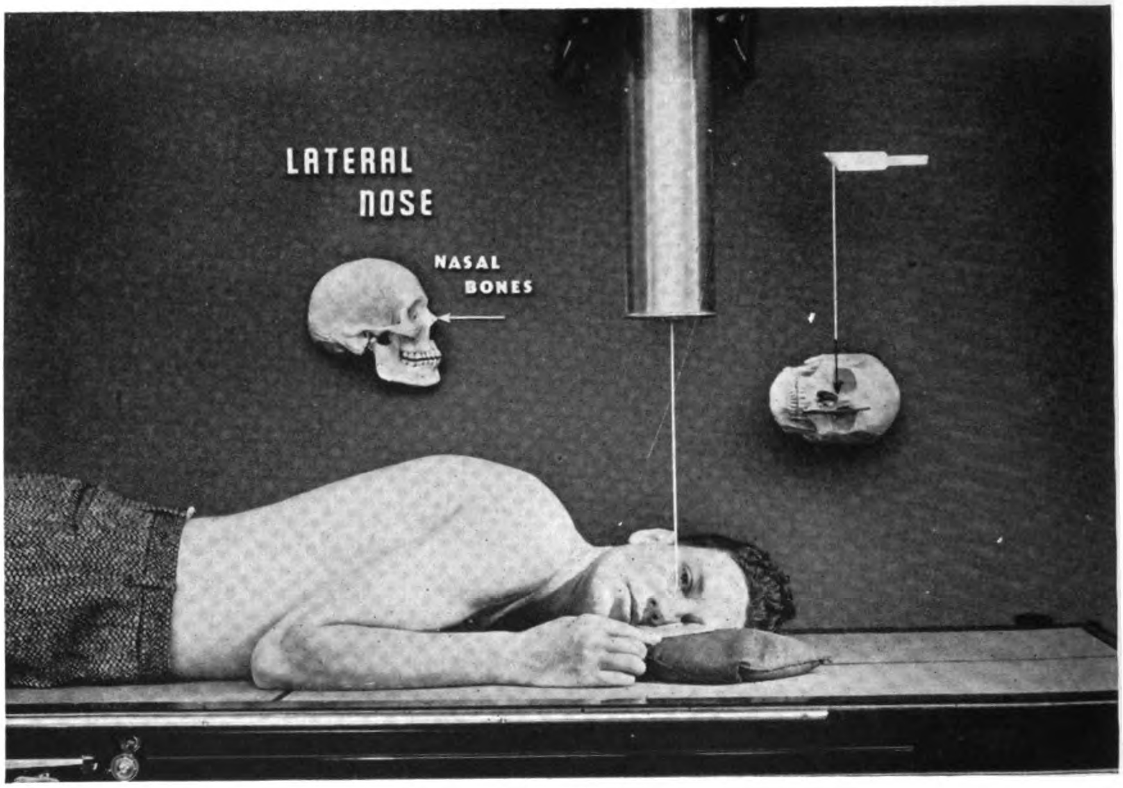


FIG. 322a

Nose, Lateral

The patient is placed in the prone position with the head turned to one side. An occlusal film is placed under the nose and is supported by sandbags. The central ray is directed to the base of the bridge of the nose.

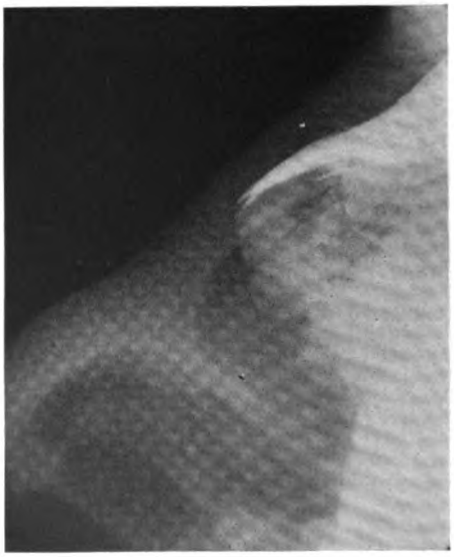


FIG. 322b

PROCEDURE

- Size of film employed—usually 2¼ by 3 (occlusal)
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—3 centimeters
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 25 milliampere-seconds, 40-inch distance, 50 kilovolts peak

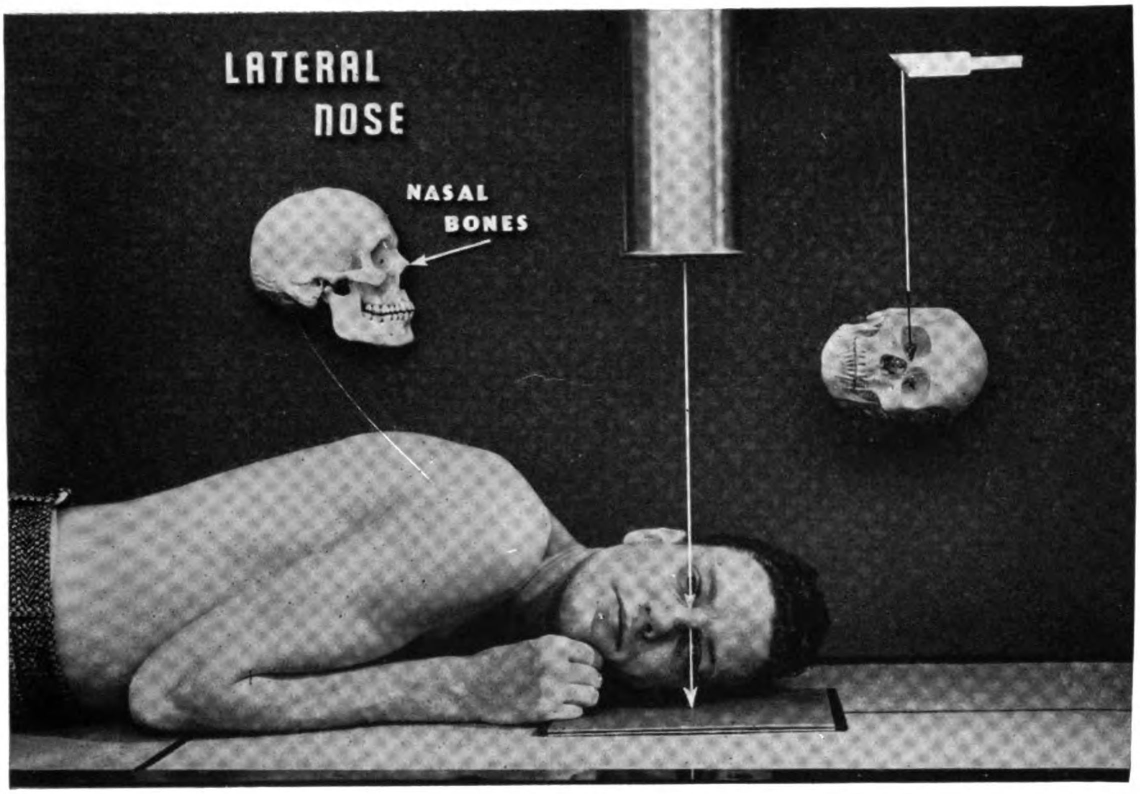


FIG. 323a

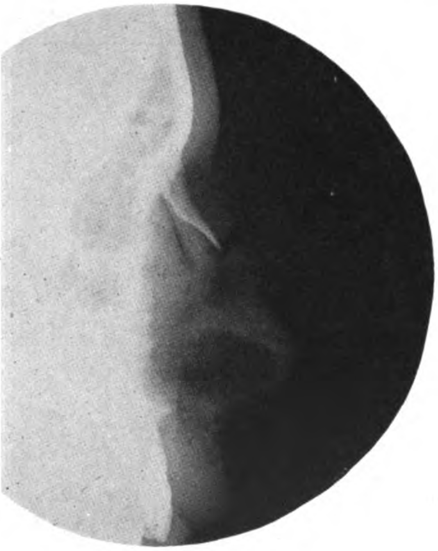


FIG. 323b

Nose, Lateral

The patient is placed in the prone position with the head in the lateral position. This may best be accomplished by having the patient place one arm at the side while the opposite arm is flexed, using the fist to support the chin. The median line of the head must be horizontal and the interorbital line vertical to the table top. The film is centered to the interorbital line from the side of the table, and to the base of the bridge of the nose from the end of the table. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—3 centimeters
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 40-inch distance, 50 kilovolts peak

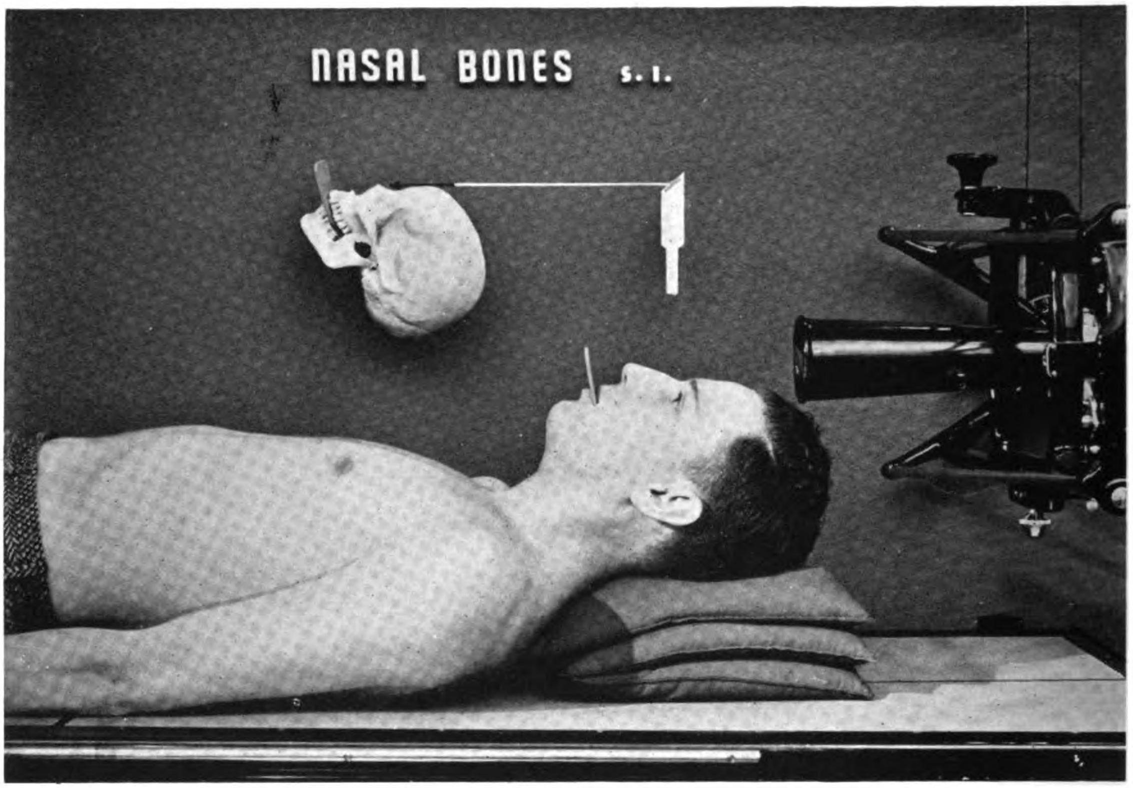


Fig. 324a

Nasal Bones, Supero-Inferior

The patient is placed on the table in the supine position with the head supported by sandbags. An occlusal film is held firmly in the mouth. The tube is placed at 90 degrees to the plane of the film, and the central ray is directed along the median line of the head just above the frontal prominence.

PROCEDURE

- Size of film employed—2¼ by 3 (occlusal)
- Variation in kilovolts peak per centimeter thickness without screens—2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—5 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—4 kilovolts peak without screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 55 kilovolts peak

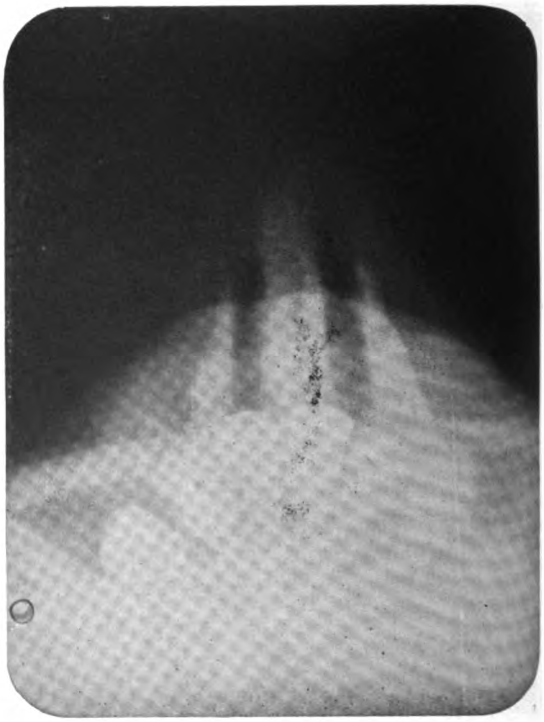


Fig. 324b

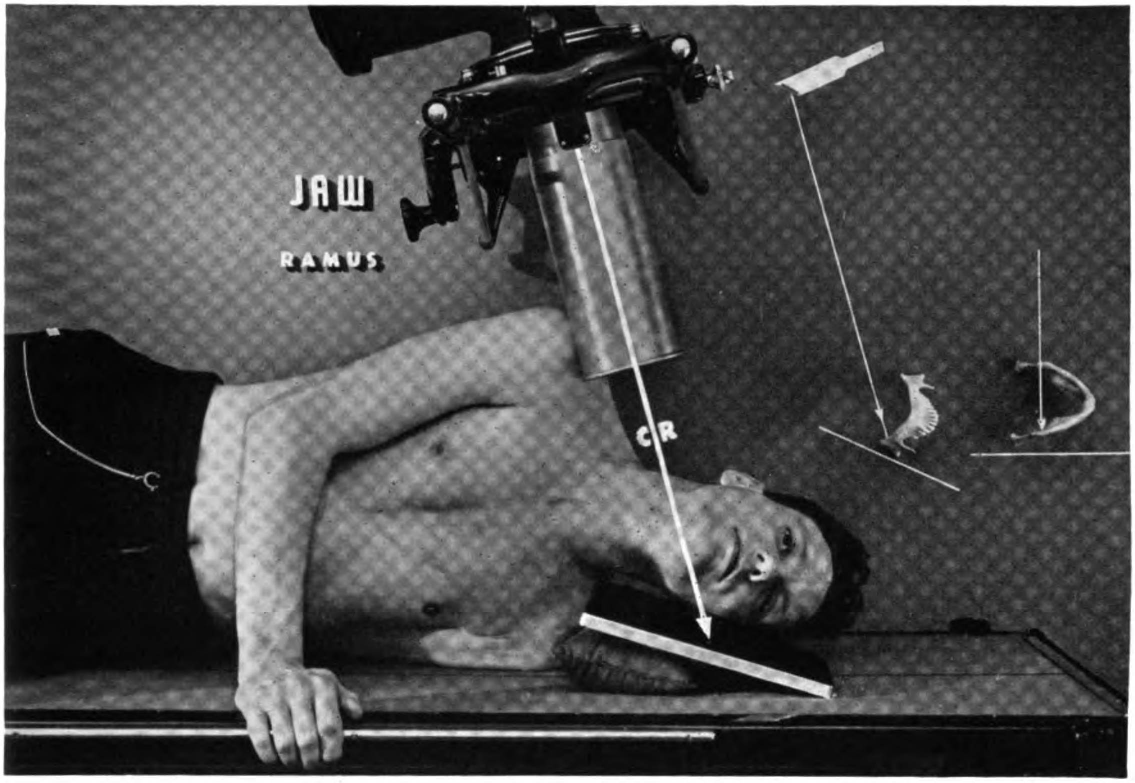


FIG. 325a

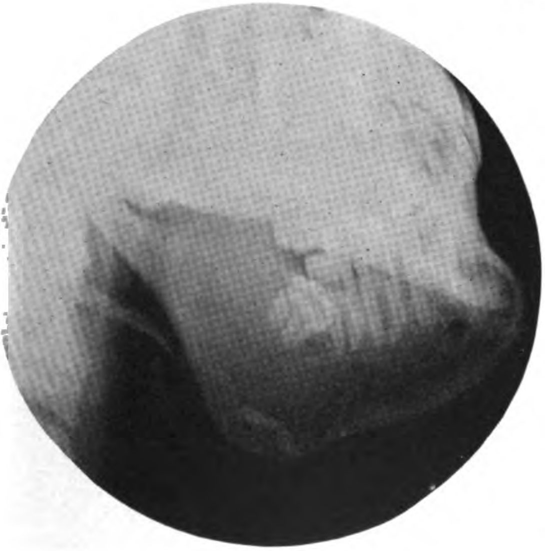


FIG. 325b

Jaw, Ramus

The end of the cassette nearest the shoulder of the patient is elevated two to three inches with a sandbag. The patient is placed in the lateral position, arm under the body, with the jaw to be radiographed next to the film. With the chin elevated, the median line of the head is parallel and the interorbital line vertical to the cassette. When viewed from the side of the table the centerline of the cassette should fall directly beneath the separation of the lips, and when viewed from the end of the table the crossline should fall beneath the angle of the mandible. The tube is tilted approximately 15 degrees toward the patient's head and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—11 centimeters through lower jaw
- Average variation in kilovolts peak minimum to maximum thickness for this part—8 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**

  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 40 kilovolts peak

  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 42 kilovolts peak

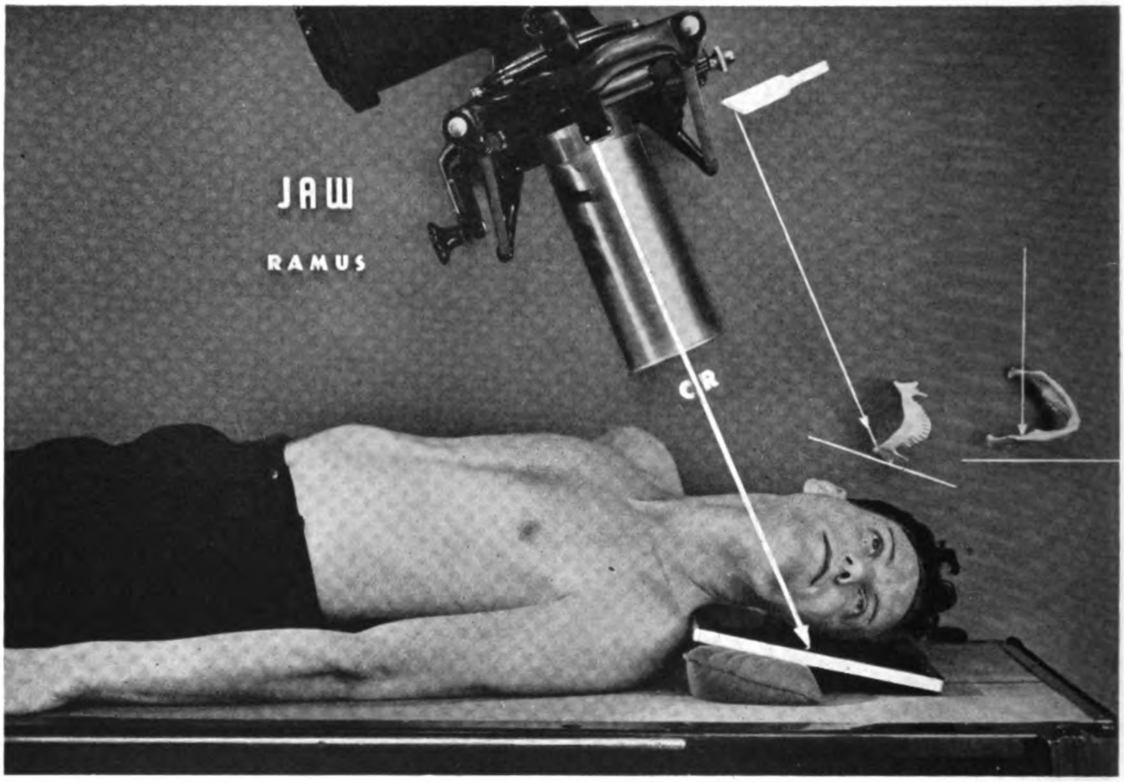


FIG. 326a

Jaw, Ramus

The end of the cassette nearest the shoulder of the patient is elevated two to three inches with a sandbag. The patient is placed in the supine position, with the head turned to one side facing the front of the table. The shoulder next to the back of the table is elevated with a sandbag. With the chin elevated, the median line of the head is parallel, and the interorbital line vertical to the cassette. When viewed from the side, the centerline of the cassette should fall directly beneath the separation of the lips, and when viewed from the end the crossline should fall beneath the angle of the mandible. The tube is tilted approximately 20 degrees toward the patient's head and the central ray is directed to the center of the film.

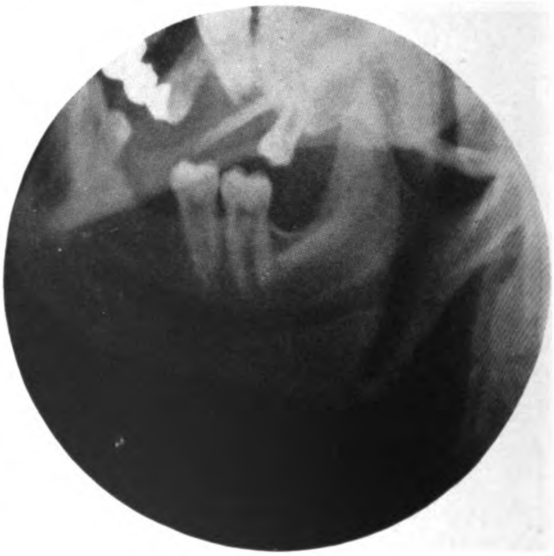


FIG. 326b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—11 centimeters through lower jaw
- Average variation in kilovolts peak minimum to maximum thickness for this part—8 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**

  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 40 kilovolts peak

  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 42 kilovolts peak

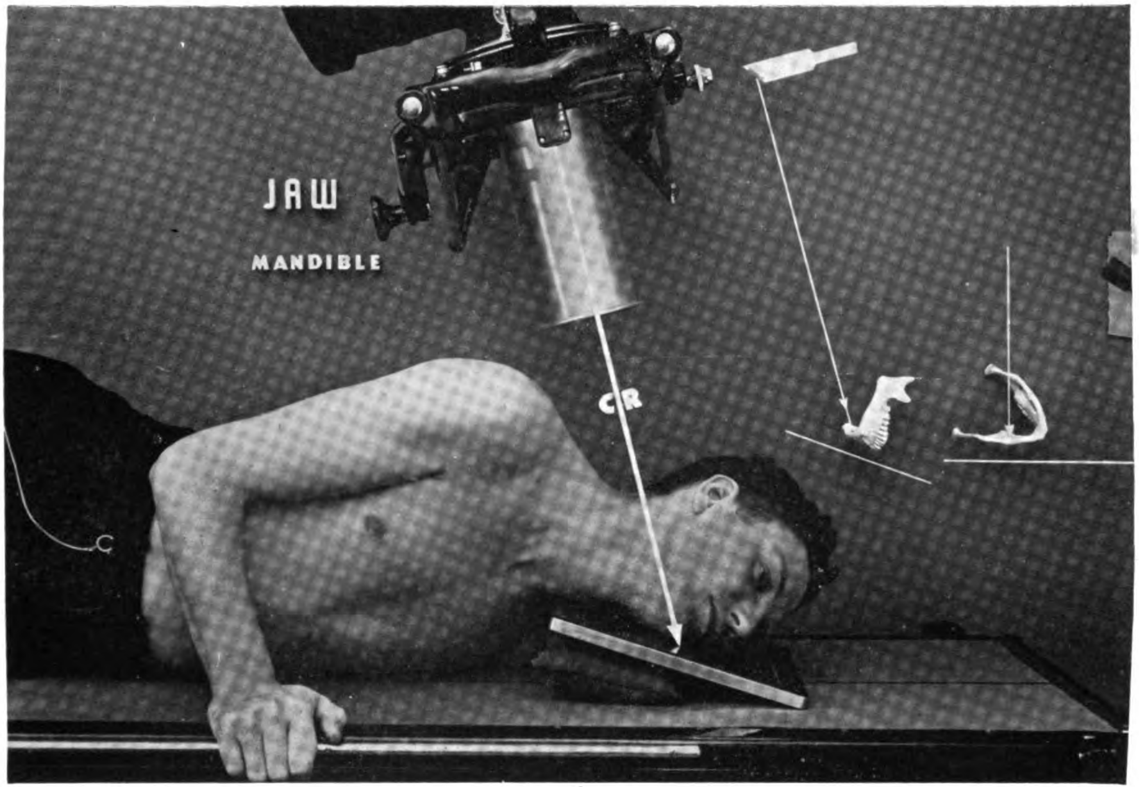


FIG. 327a

Jaw, Mandible

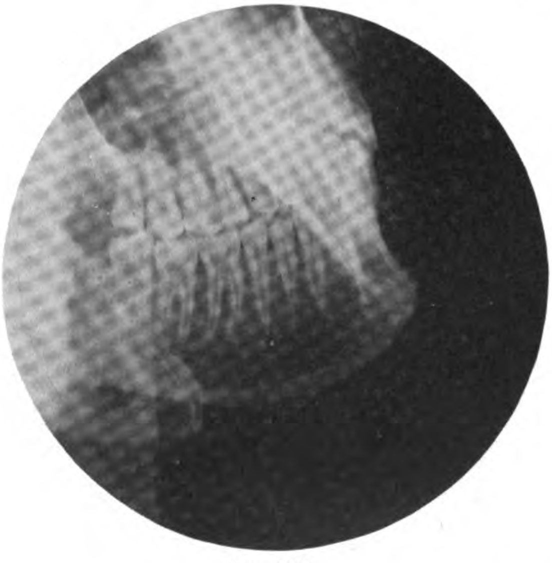


FIG. 327b

The end of the cassette next to the patient's shoulder is elevated two to three inches with a sandbag. The patient is placed in the prone position with the jaw to be radiographed next to the film. Let the patient come to rest in a most comfortable position. This will give the operator correct rotation for the lower jaw. The chin is elevated to avoid superimposition of the mandible over the cervical spine. When viewed from the side of the table the centerline of the cassette should fall directly beneath the separation of the lips, and when viewed from the end the crossline should fall beneath the angle of the mandible. The tube is tilted approximately 15 degrees toward the patient's head and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—11 centimeters through lower jaw.
- Average variation in kilovolts peak minimum to maximum thickness for this part—8 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 40 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 42 kilovolts peak

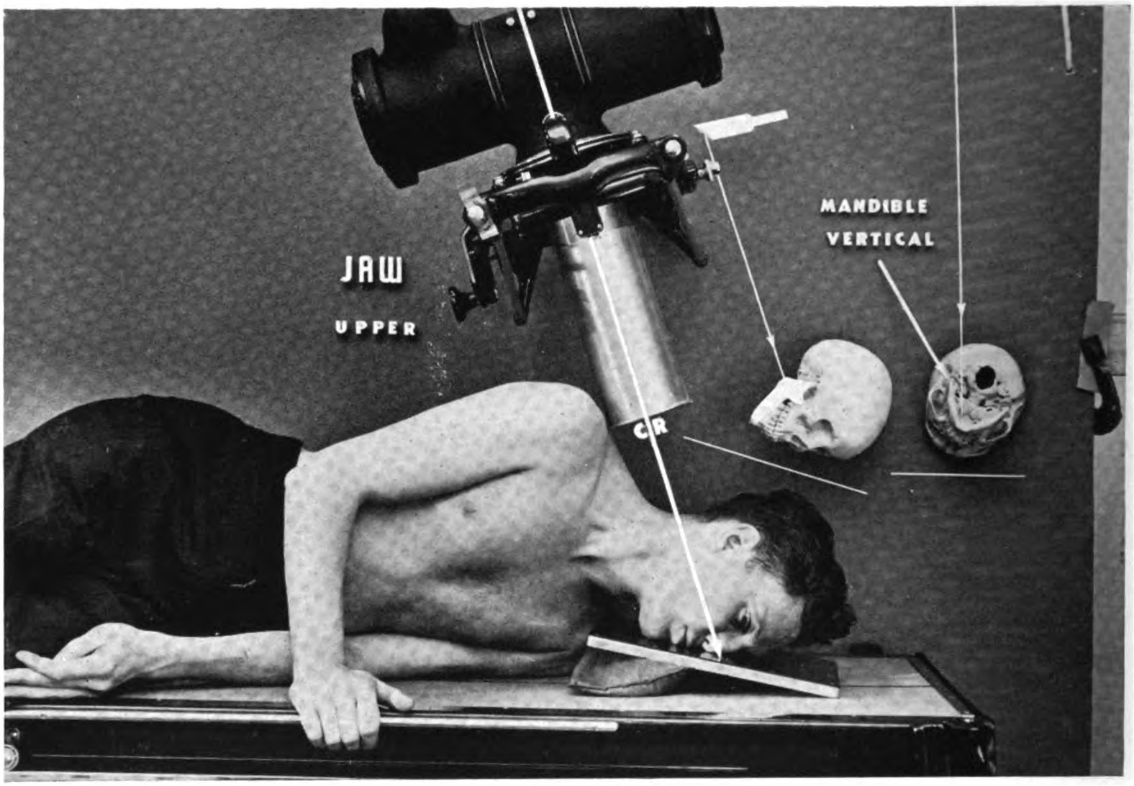


FIG. 328a

Jaw, Upper

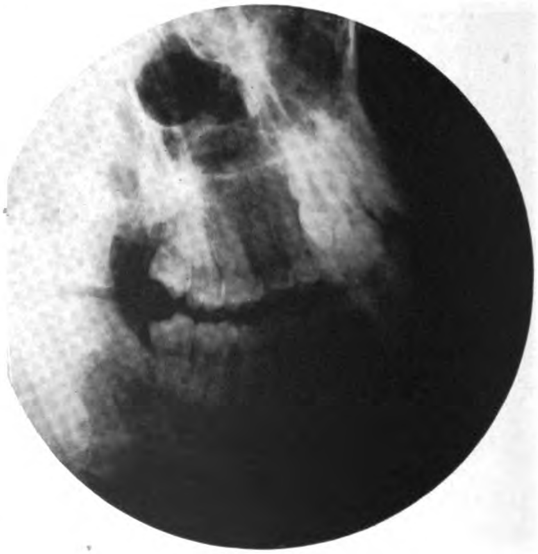


FIG. 328b

The end of the cassette next to the patient's shoulder is elevated two to three inches with a sandbag. The patient is placed in the lateral position lying directly on one shoulder. The arm nearer the tube is pulled forward and used for support. This places the patient in a slightly oblique position. The head rests on the cheek, nose, and chin. When viewed from the side, the centerline of the cassette should fall beneath the separation of the lips, and when viewed from the end, the crossline should fall beneath the angle of the mandible. The mandible farthest away from the film must be in the vertical position. The tube is tilted approximately 15 degrees toward the patient's head and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—16 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 56 kilovolts peak
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak

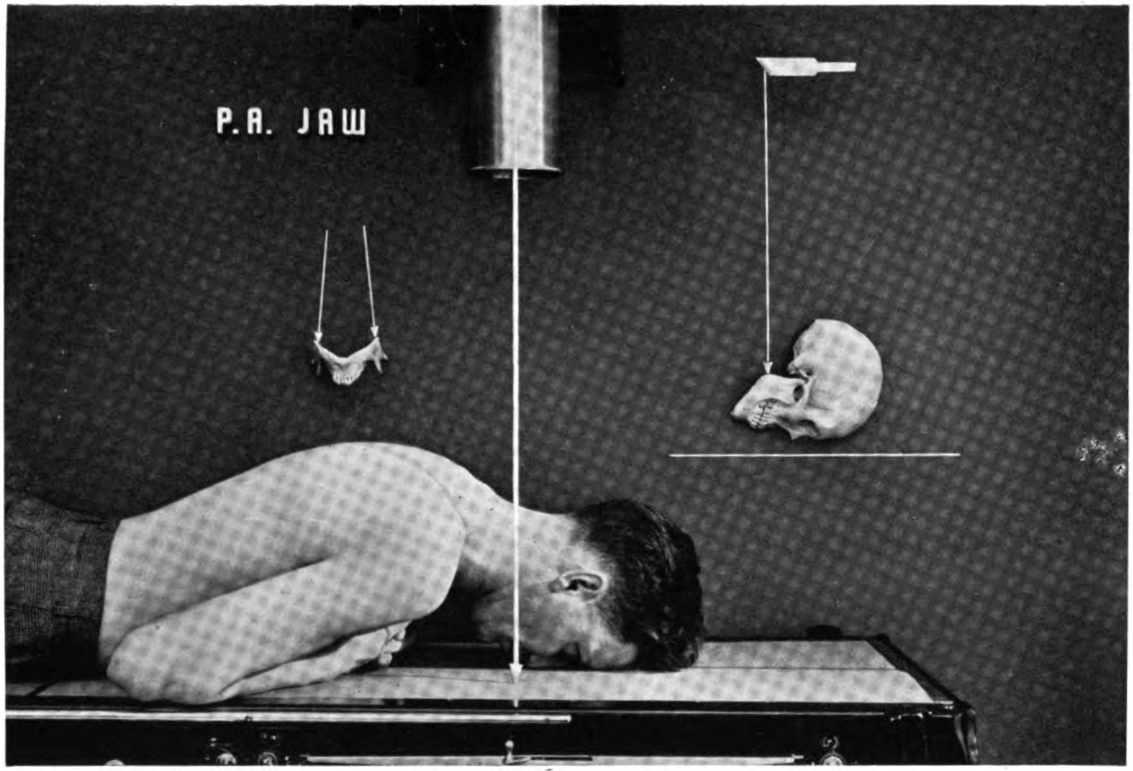


FIG. 329a

Jaw, Postero-Anterior

The patient is placed in the prone position with the hands under the chest. The median line of the head is located over the centerline of the table. The line between the outer canthus of the eye and the external auditory meatus must be vertical to the table top. The film is centered to the junction of the upper and lower lips from the side of the table. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—16 centimeters.
- Average variation in kilovolts peak minimum to maximum thickness for this part—14 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 56 kilovolts peak

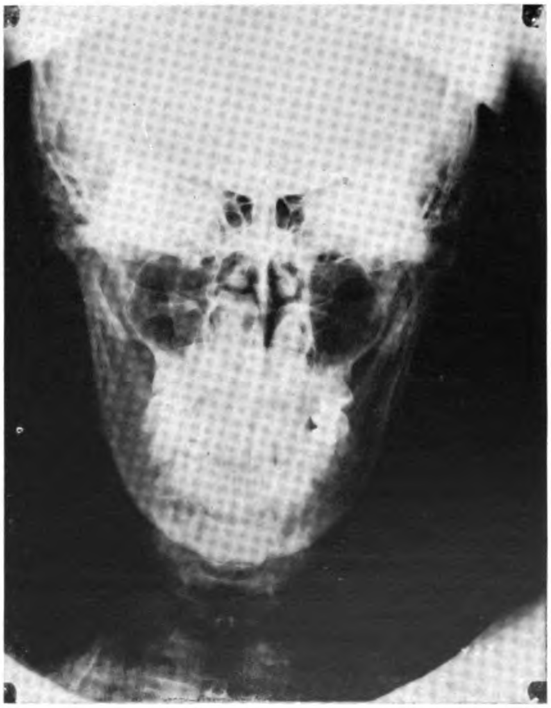


FIG. 329b

With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak

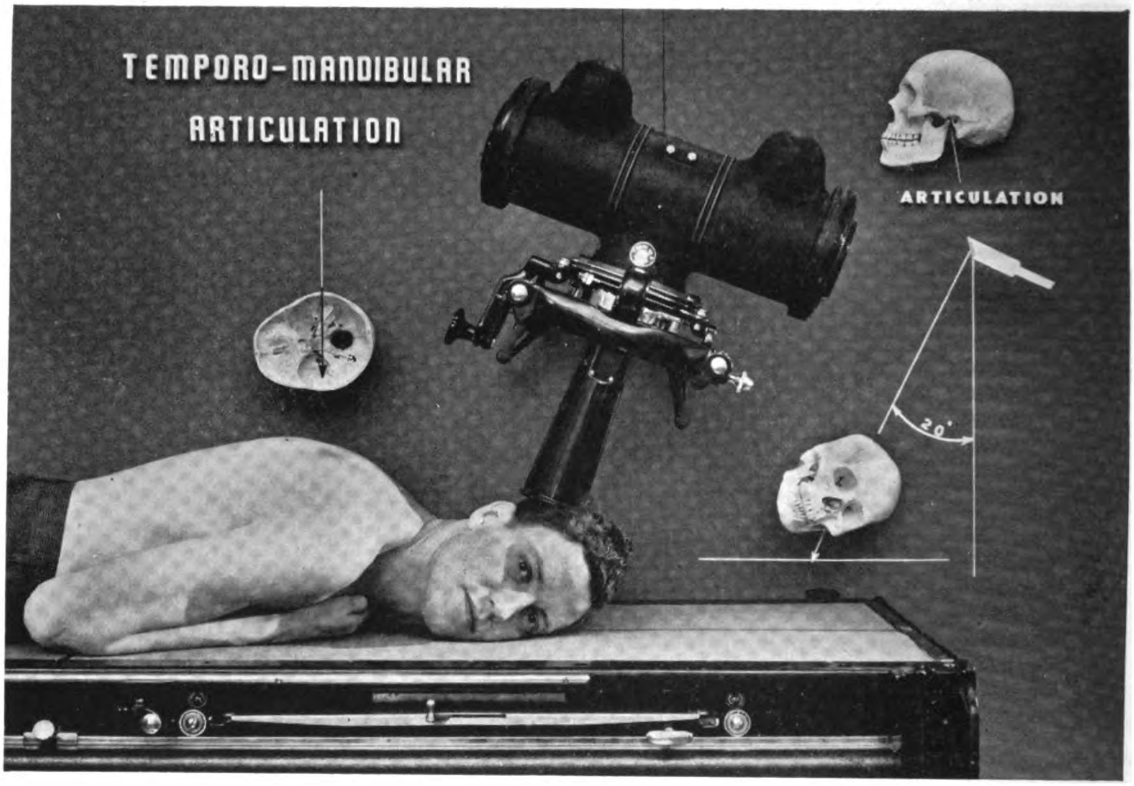


FIG. 330a

Temporo-Mandibular Articulation, Lateral

The patient is placed in the prone position with one arm at the side and the other arm used for support. With the head resting in a natural and relaxed manner, the external auditory meatus is placed over the table centerline. The film is centered to the same landmark from the side of the table. The tube is tilted 20 degrees toward the patient's feet, and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—8 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 54 kilovolts peak

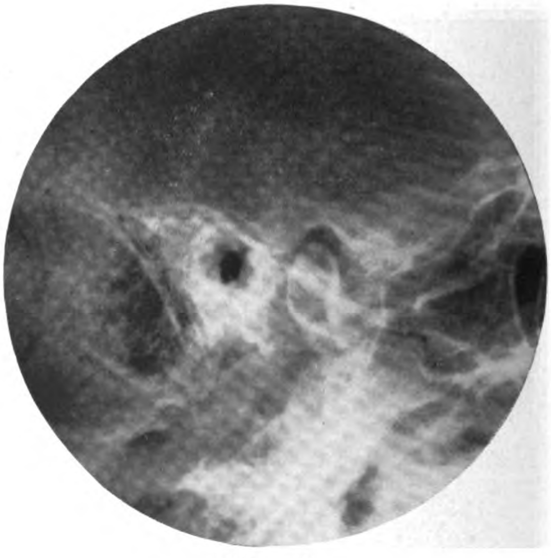


FIG. 330b

With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 58 kilovolts peak

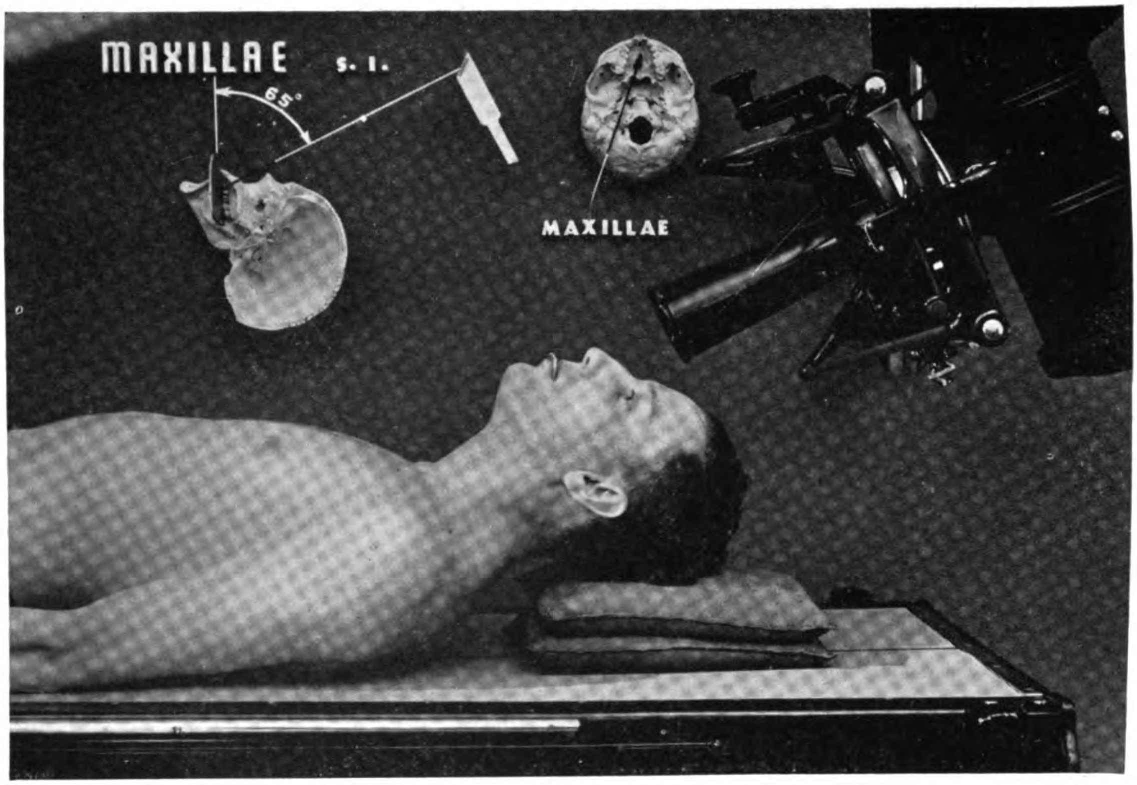


FIG. 331a

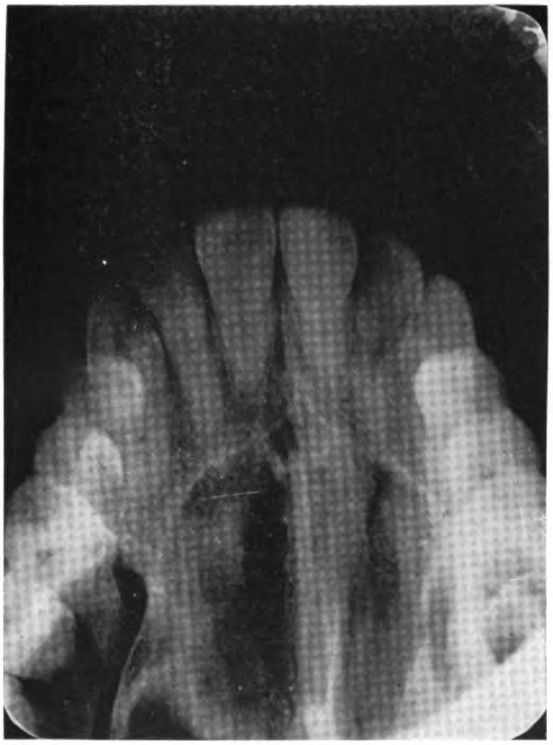


FIG. 331b

Maxilla, Supero-Inferior

With the patient in the supine position, the head is supported by sandbags until the occlusal surface of the upper teeth is vertical to the table top. An occlusal film is put in the mouth as far as possible. The tube is tilted 65 degrees toward the feet, and the central ray is directed to the junction of the nose and upper lip.

PROCEDURE

- Size of film employed—2¼ by 3 (occlusal)
- Variation in kilovolts peak per centimeter thickness without screens—3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—7 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—4 kilovolts peak without screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 50 milliampere-seconds, 22-inch distance, 55 kilovolts peak

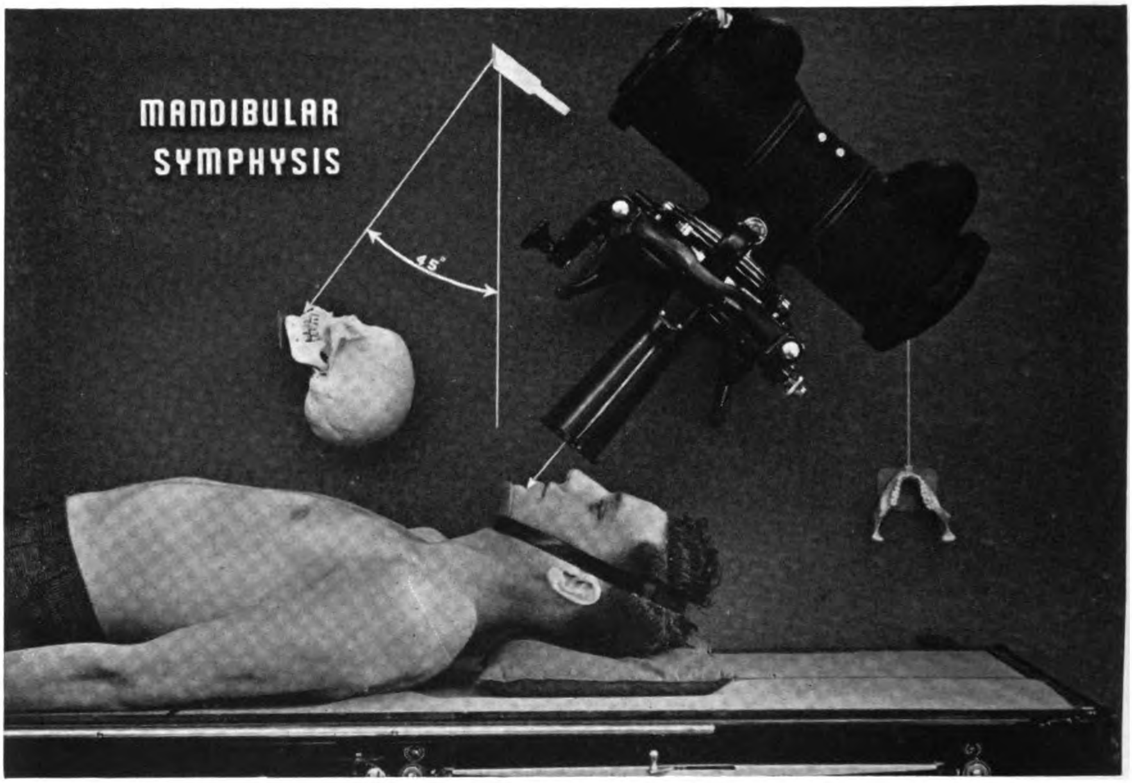


FIG. 332a

Mandibular Symphysis

The patient is placed in the supine position with the head supported by a sandbag. An occlusal film is taped against the inferior border of the mandible. The tube is tilted until the central ray forms an angle of 45 degrees with the mandibular symphysis. The central ray is directed to a point on the median line halfway between the tip of the chin and the lower lip.

PROCEDURE

- Size of film employed—2¼ by 3 (occlusal)
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—4 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—4 kilovolts peak without screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 25 milliampere-seconds, 22-inch distance, 55 kilovolts peak

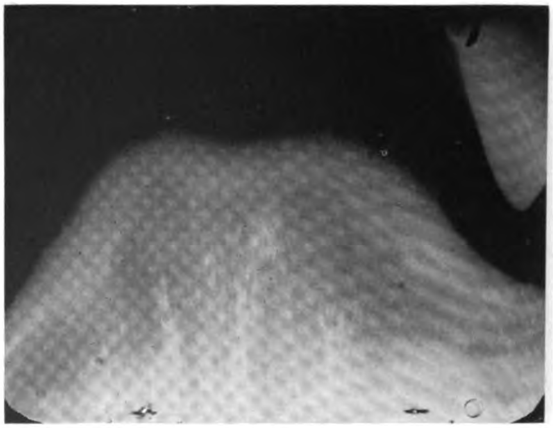


FIG. 332b

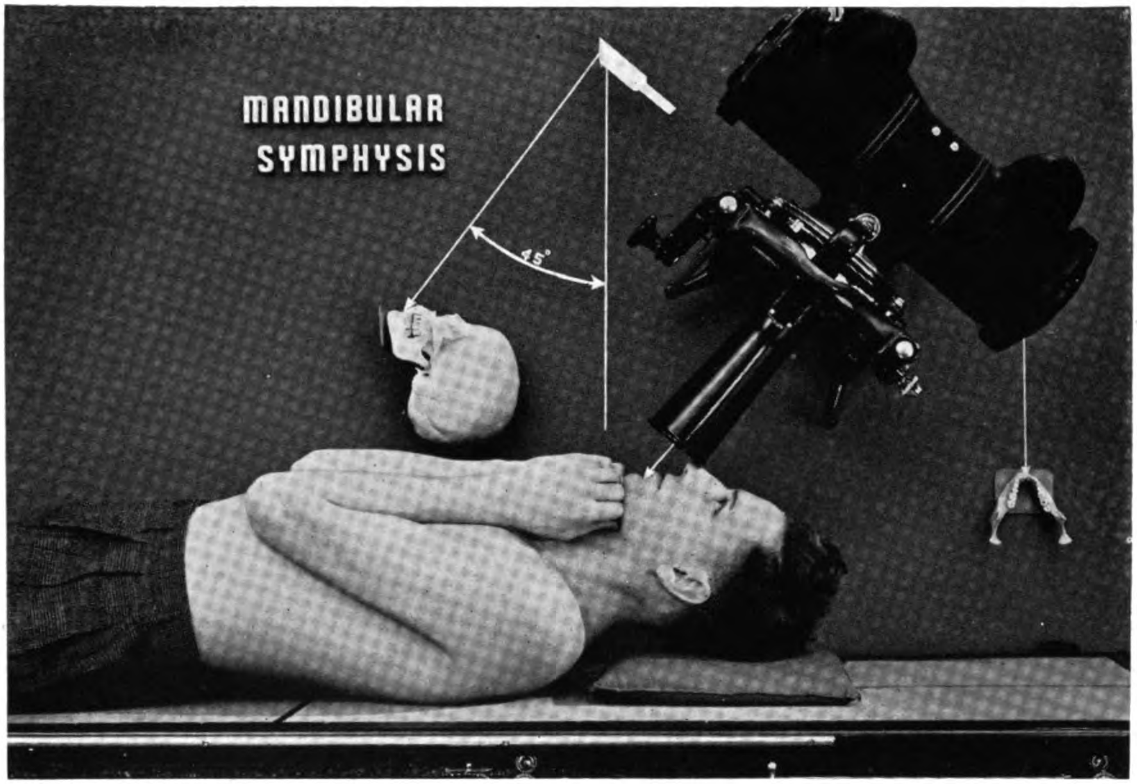


FIG. 333a

Mandibular Symphysis

The patient is placed in the supine position with the head supported by a sandbag. The patient holds an occlusal film against the inferior border of the mandible. The tube is tilted until the central ray forms an angle of 45 degrees with the mandibular symphysis. The central ray is directed to a point on the median line halfway between the tip of the chin and the lower lip.

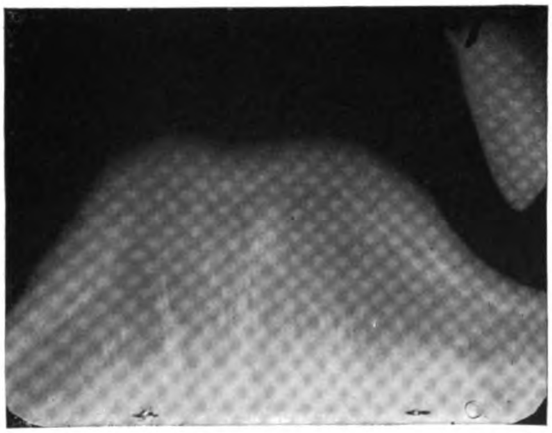


FIG. 333b

PROCEDURE

- Size of film employed—2¼ by 3 (occlusal)
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—4 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—4 kilovolts peak without screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 25 milliampere-seconds, 22-inch distance, 55 kilovolts peak

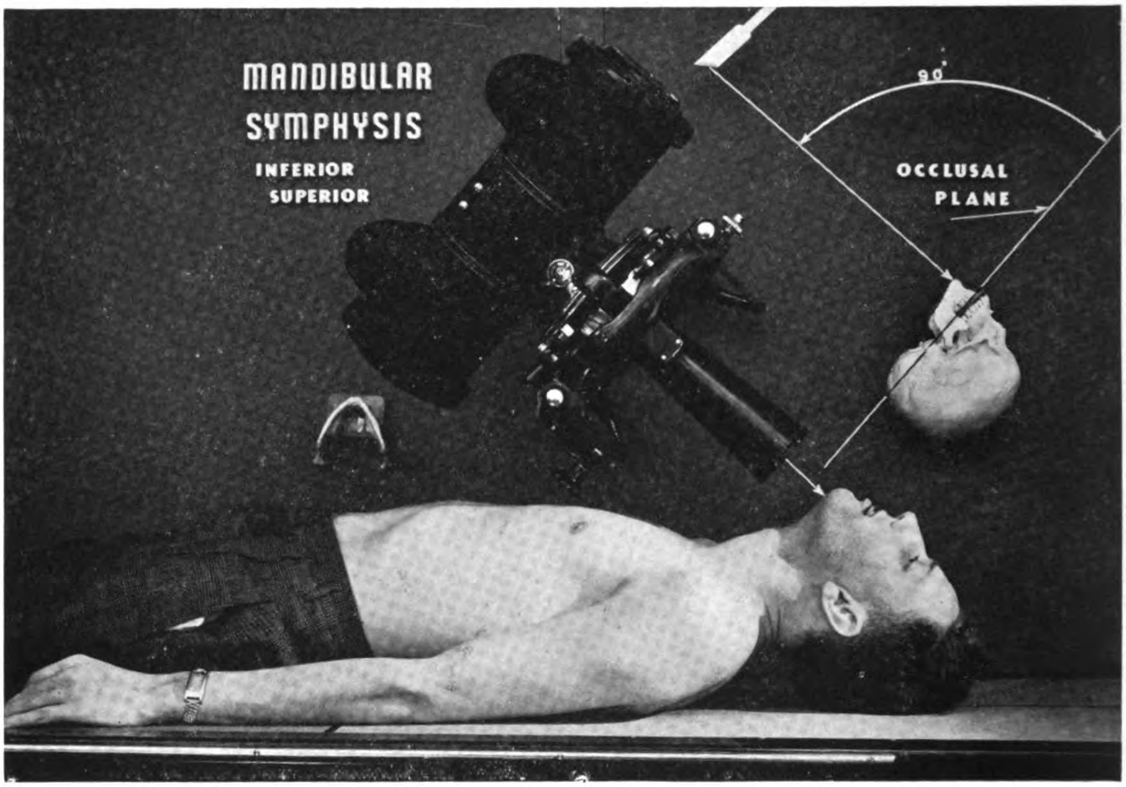


FIG. 334a

Mandibular Symphysis, Infero-Superior

The patient is placed on the table in the supine position with the back of the head resting on the table. An occlusal film is put in the mouth as far as possible. The tube is tilted until the central ray is at 90 degrees to the occlusal plane. The central ray is directed to the inferior border of the mandibular symphysis.

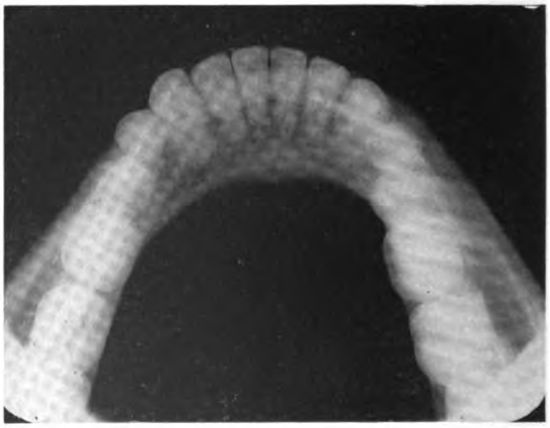


FIG. 334b

PROCEDURE

- Size of film employed—2¼ by 3 (occlusal)
- Variation in kilovolts peak per centimeter thickness without screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—4 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—4 kilovolts peak without screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  Without screens, without Potter-Bucky diaphragm, 25 milliampere-seconds, 22-inch distance, 55 kilovolts peak

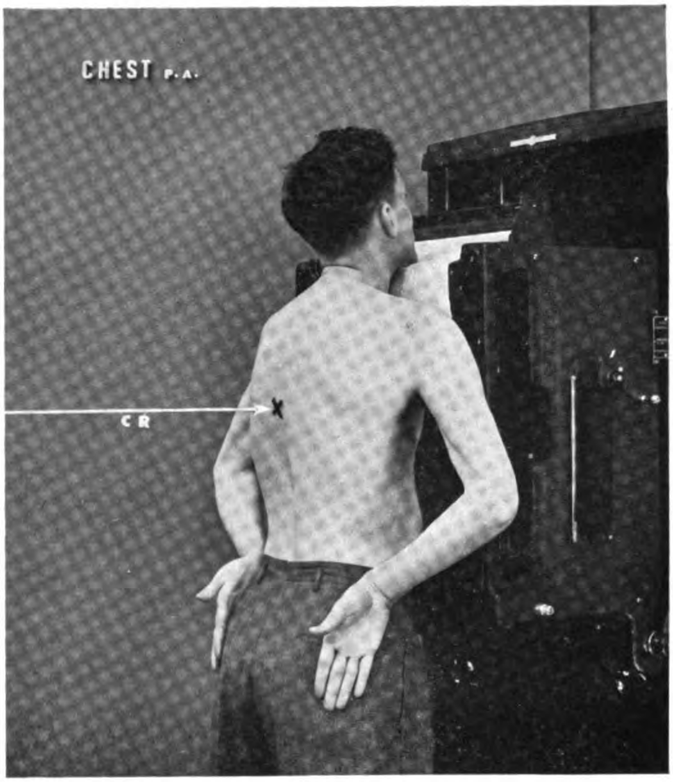


FIG. 335a

Chest, Postero-Anterior, Upright

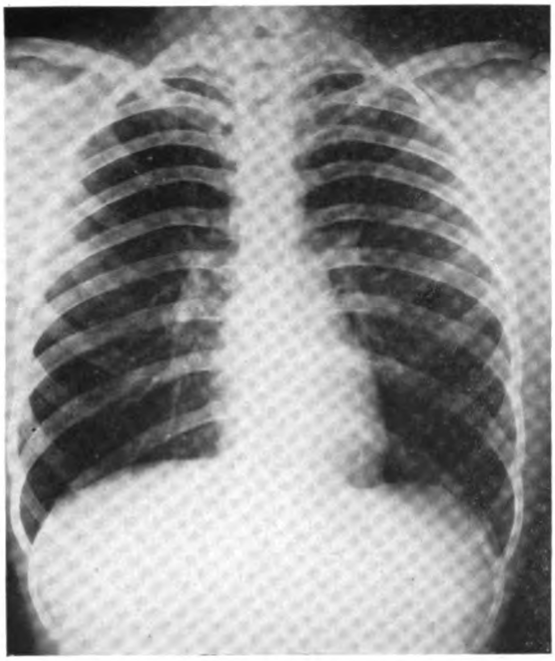


FIG. 335b

The patient is placed in the upright position facing the cassette holder. The median line of the body is located over the centerline of the film. The chin is raised and rests on top of the cassette holder. The acromion processes should be positioned 2 to 3 inches below the upper corner of the cassette. The elbows are flexed with the back of the hands resting on the hips, and the shoulders are brought forward as far as possible. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters. This thickness is measured at full expiration
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 10 milliampere-seconds, 72-inch distance, 60 kilovolts peak

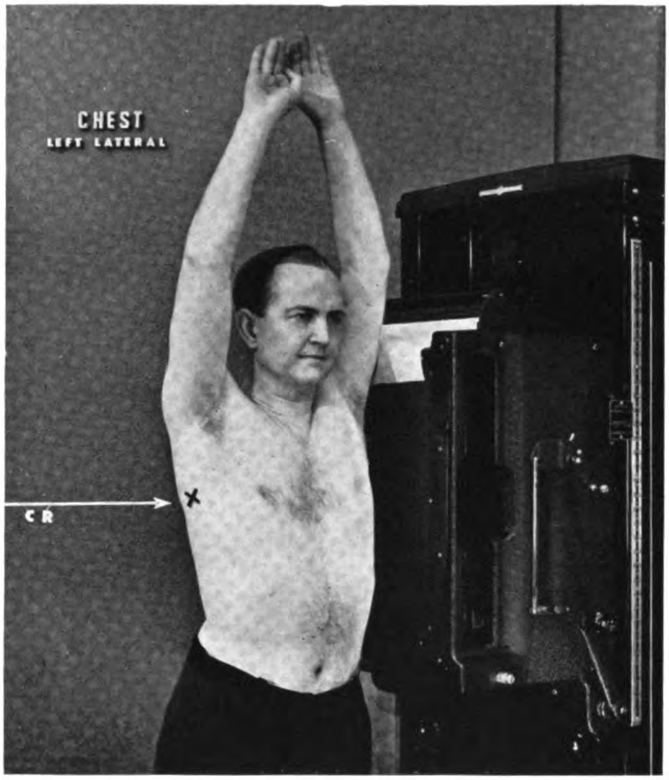


FIG. 336a

Chest, Left Lateral, Upright

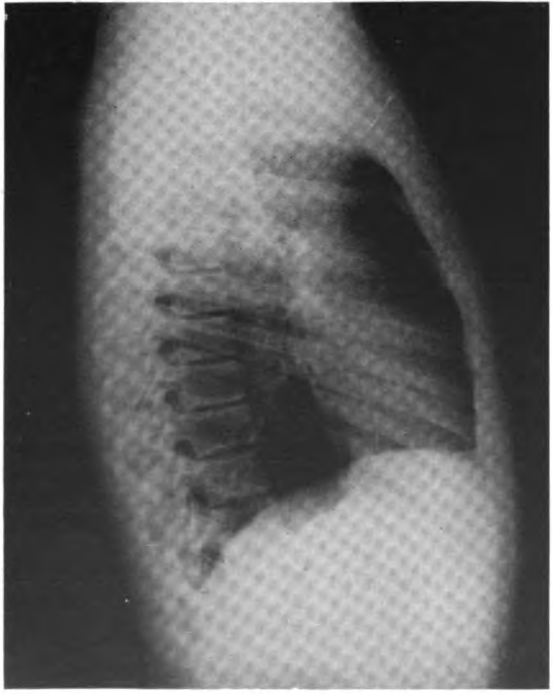


FIG. 336b

With the patient in the upright position, the arms are extended over the head, and the left side of the body is placed in contact with the cassette holder. The cassette holder is adjusted to the same height as is used for the postero-anterior chest. A point on the side of the body midway between the sternum and the tips of the spinous processes is centered to the centerline of the film. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—30 centimeters. This thickness is measured at full expiration
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 20 milliampere-seconds, 72-inch distance, 66 kilovolts peak

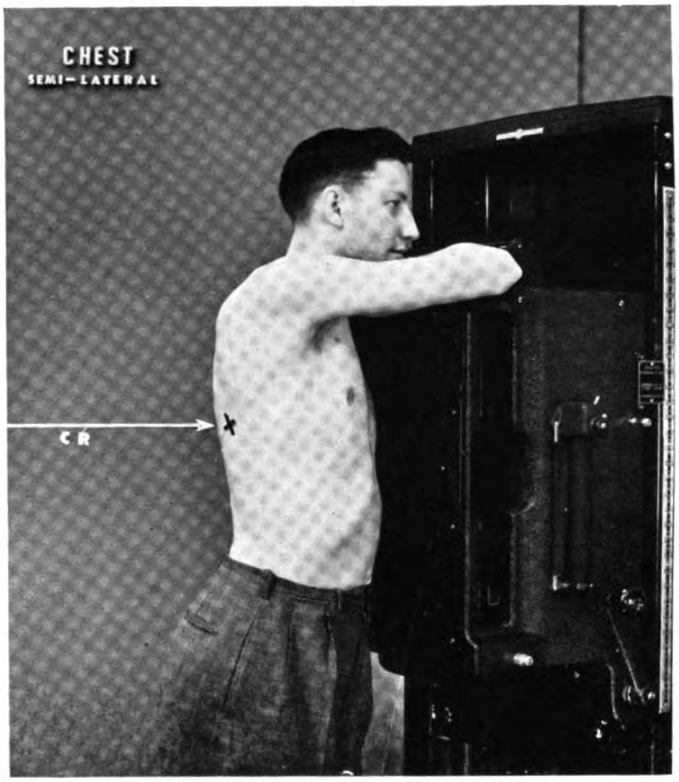


Fig. 337a

Chest, Semi-Lateral, Upright

Ordinarily the left side of the body is placed next to the film. The cassette holder is adjusted to the same height as is used for the postero-anterior chest. The patient is placed in the upright position before the cassette holder in the semi-lateral position. The left side is placed against the cassette holder, with the left arm at the side, palm outward. The median plane of the body forms an angle of 45 degrees with the film. The right arm rests on top of the cassette holder. The central ray is directed to the center of the film.

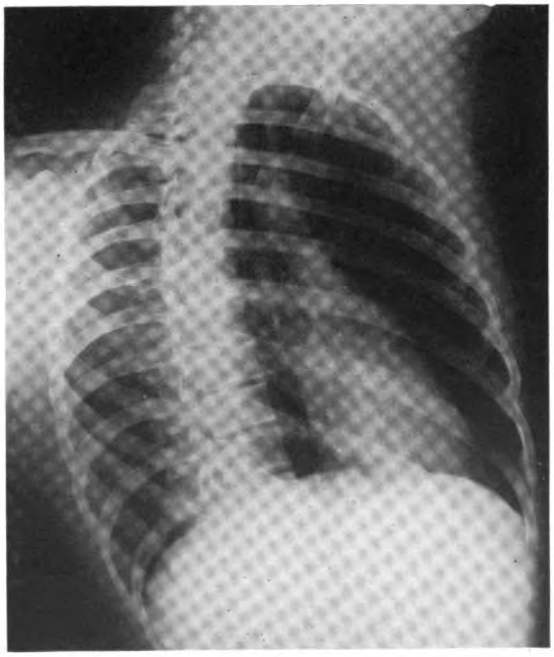


Fig. 337b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—26 centimeters. This thickness is measured at full expiration
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 20 milliampere-seconds, 72-inch distance, 58 kilovolts peak

Chest Apices, Postero-Anterior, Upright

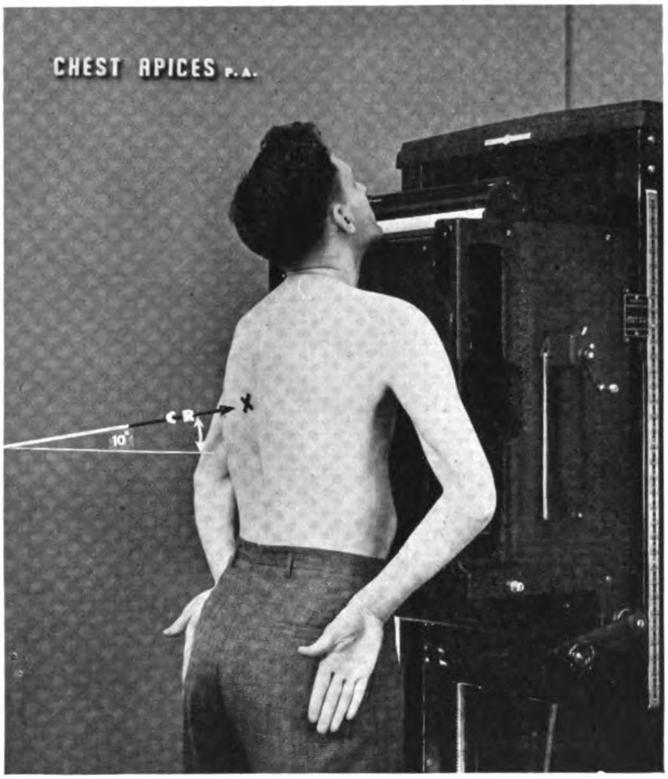


FIG. 338a

The patient is placed in the upright position facing the cassette holder. The median line of the body is placed over the centerline of the film. The chin is extended and rests on top of the cassette holder. The acromion processes should be positioned 2 to 3 inches below the upper corner of the cassette. The arms are flexed slightly with the back of the hands against the hips. The tube is tilted up 10 degrees from the horizontal and the central ray is directed to the center of the film. Angulation of the tube in this manner will project the apices above the clavicles.

PROCEDURE

- Size of film employed—usually 14 by 17, placed crosswise the patient
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters. This thickness is measured at full expiration.
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 56 kilovolts peak
  With Parspeed screens, without Potter-Bucky diaphragm, 5 milliampere-seconds, 40-inch distance, 52 kilovolts peak

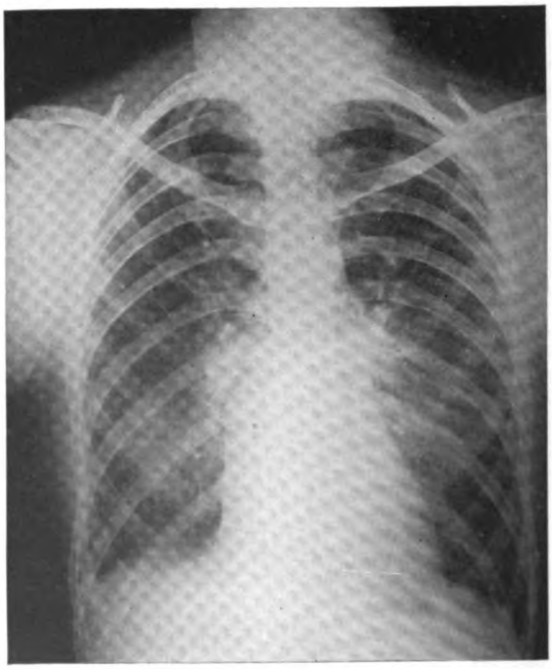


FIG. 338b

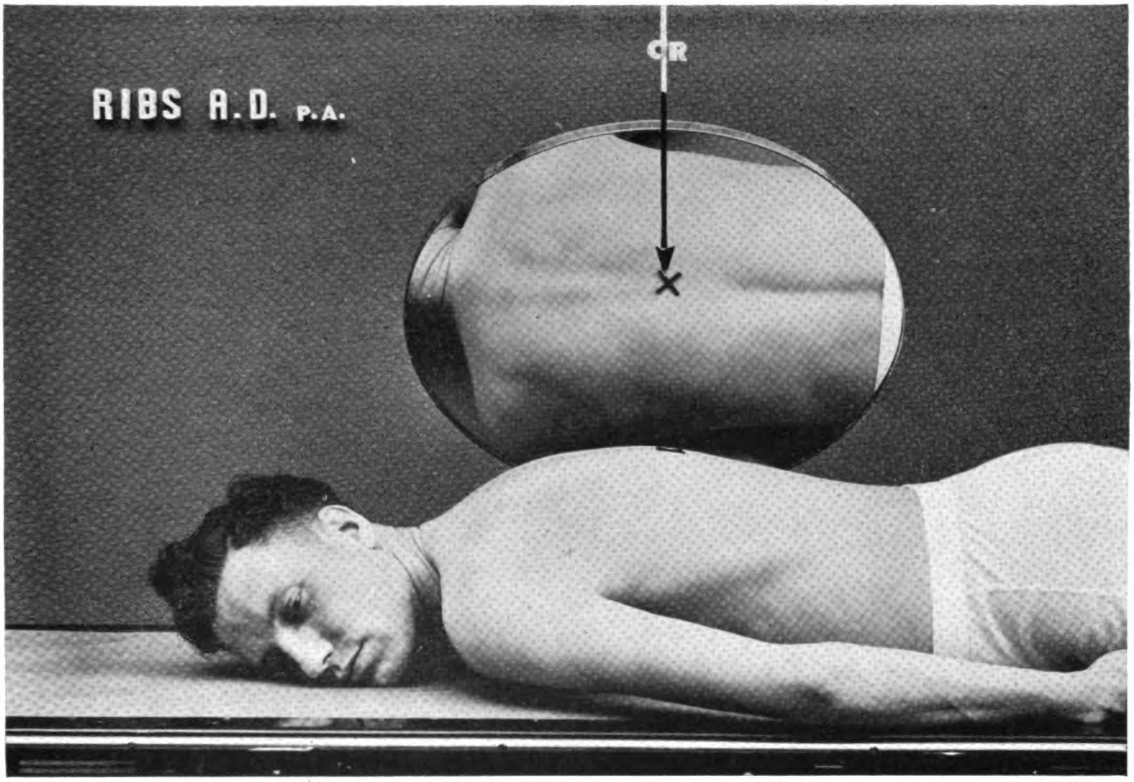


FIG. 339a

Ribs, Above Diaphragm, Postero-Anterior

The patient is placed on the table in the prone position with the median line of the body over the centerline of the table. From the side of the table the film is centered to the inferior angle of the scapula. The central ray is directed to the center of the film.

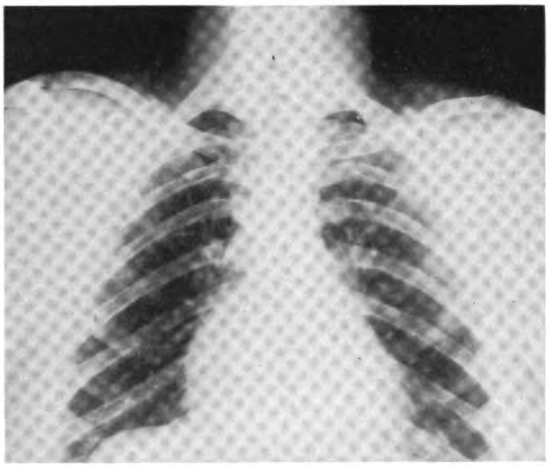


FIG. 339b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 25 milliampere-seconds, 40-inch distance, 60 kilovolts peak

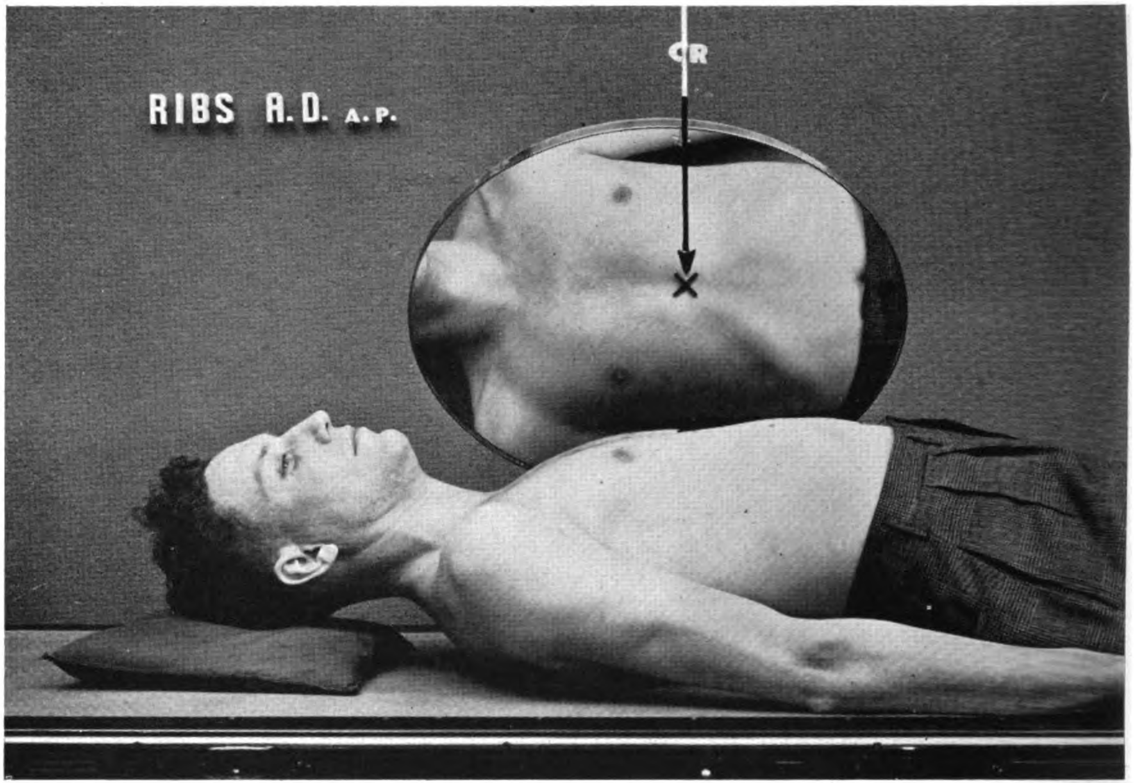


FIG. 340a

Ribs, Above Diaphragm, Antero-Posterior

The patient is placed in the supine position with the median line of the body over the centerline of the table. From the side of the table the film is centered to the inferior tip of the xyphoid process. The central ray is directed to the center of the film.

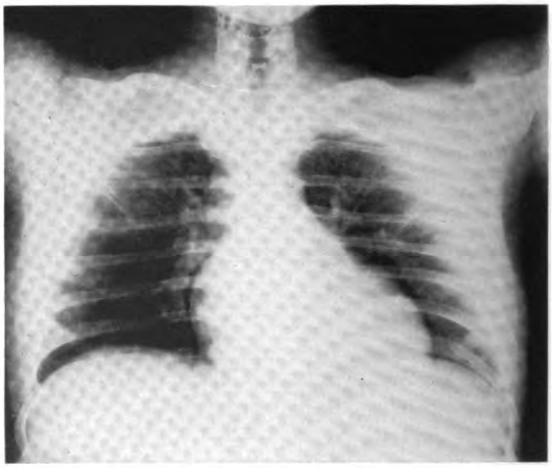


FIG. 340b

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 25 milliampere-seconds, 40-inch distance, 60 kilovolts peak

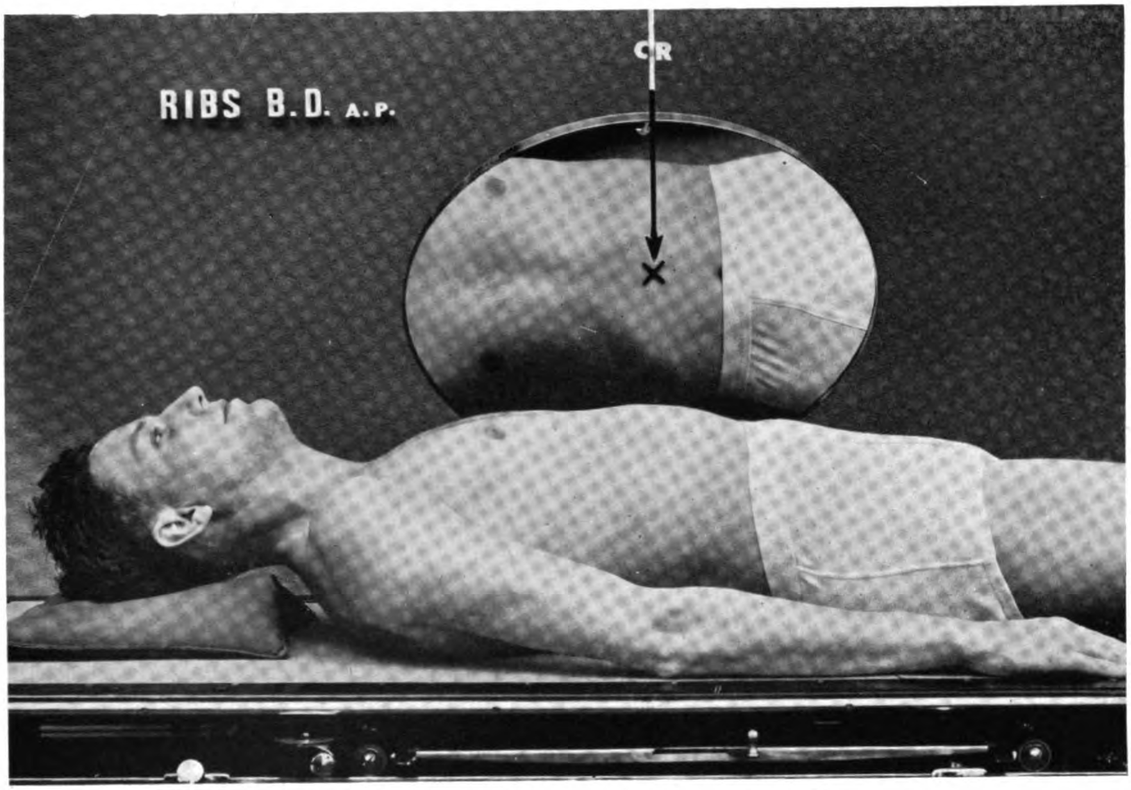


FIG. 341a

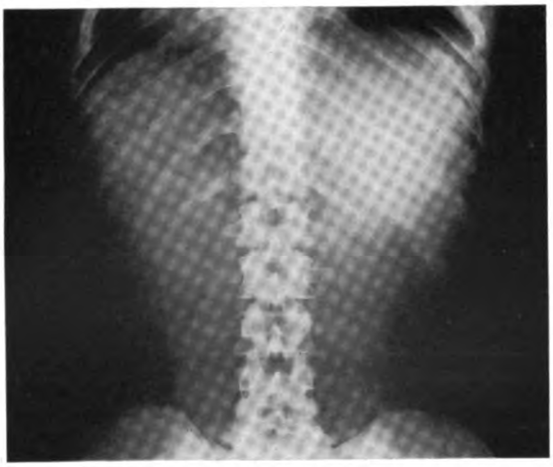


FIG. 341b

Ribs, Below Diaphragm, Antero-Posterior

The patient is placed on the table in the supine position with the median line of the body over the centerline of the table. From the side of the table the film is centered to a point on the median line three inches below the inferior tip of the xyphoid process. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17, placed crosswise the patient
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 54 kilovolts peak

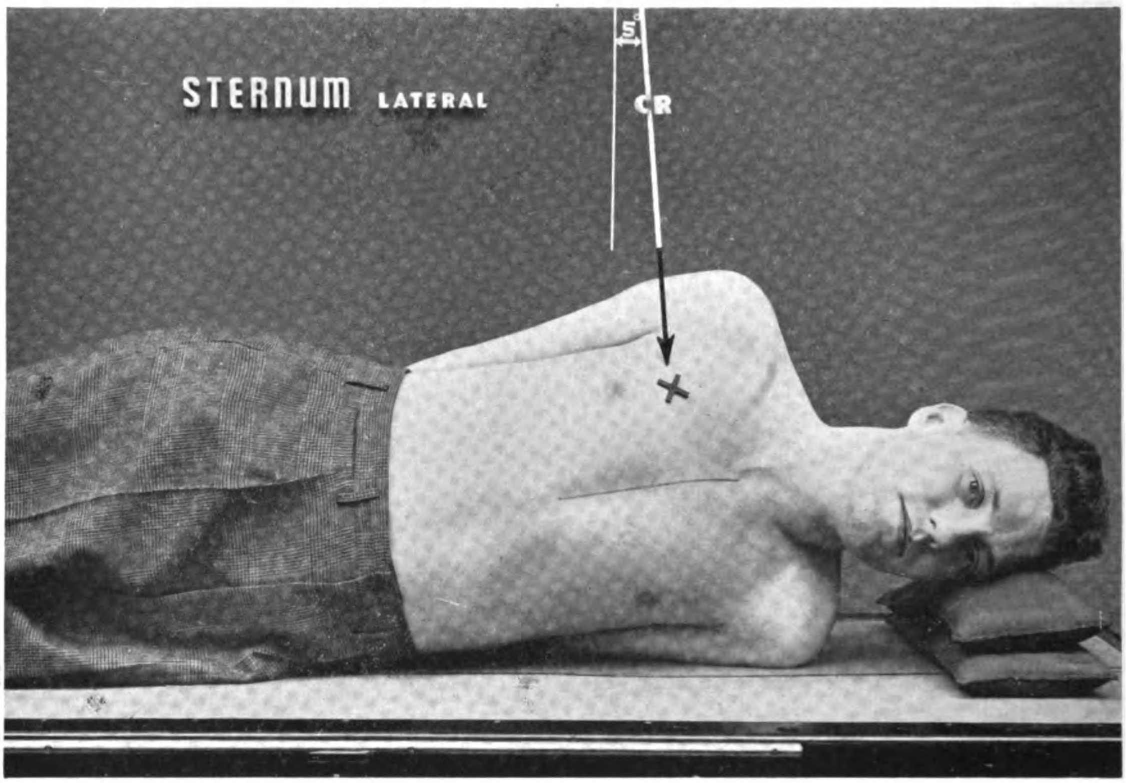


FIG. 342a

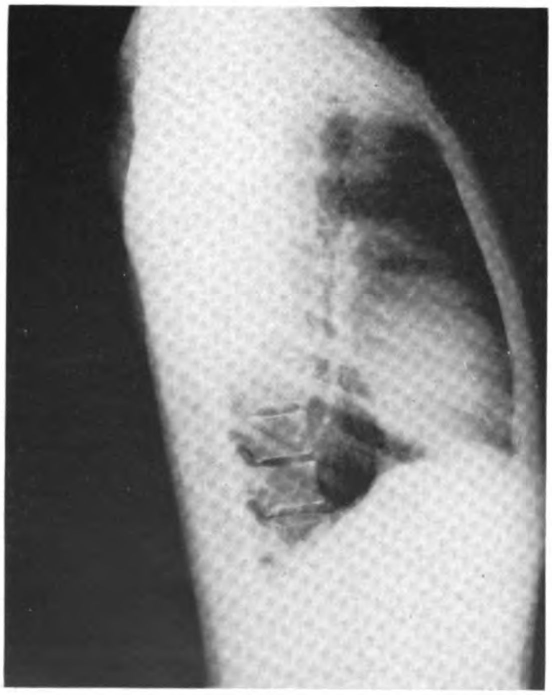


FIG. 342b

Sternum, Lateral

The patient is placed on the lateral position with the arms behind the back, and with the sternum over the centerline of the table. From the side of the table the film is centered to a point halfway between the sternal notch and the inferior tip of the xyphoid process. The tube is tilted 5 degrees toward the patient's head, and the central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—30 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 64 kilovolts peak

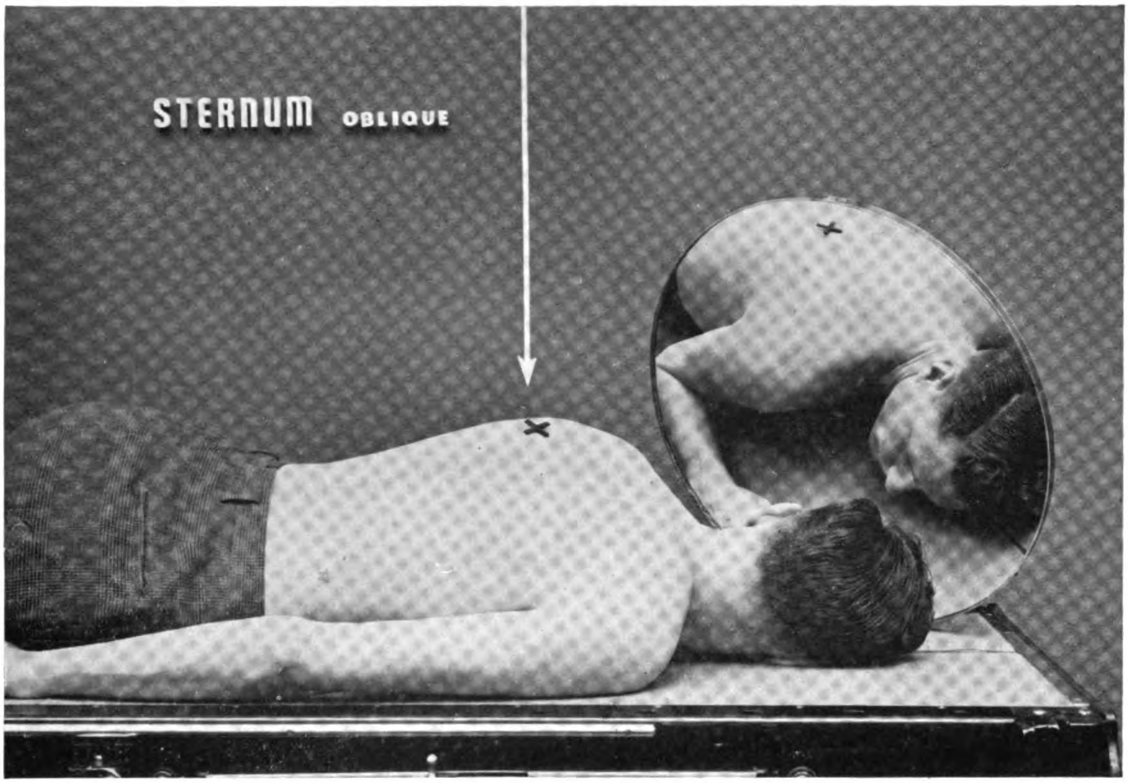


FIG. 343a

Sternum, Postero-Anterior Oblique

The patient is placed in the prone position with the median line of the body over the centerline of the table. The body is rotated slightly on the left side so that there will not be superimposition of the dorsal spine. The film is centered to the middle of the sternum from the side of the table. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—25 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—15 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 25 milliampere-seconds, 30-inch distance, 60 kilovolts peak

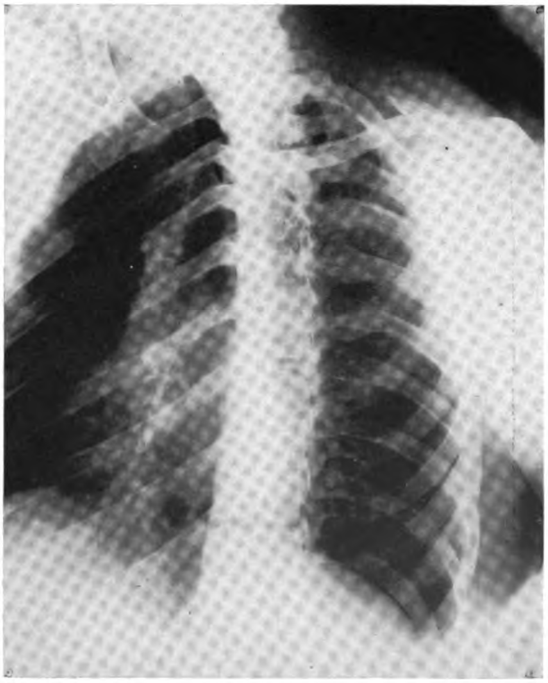


FIG. 343b

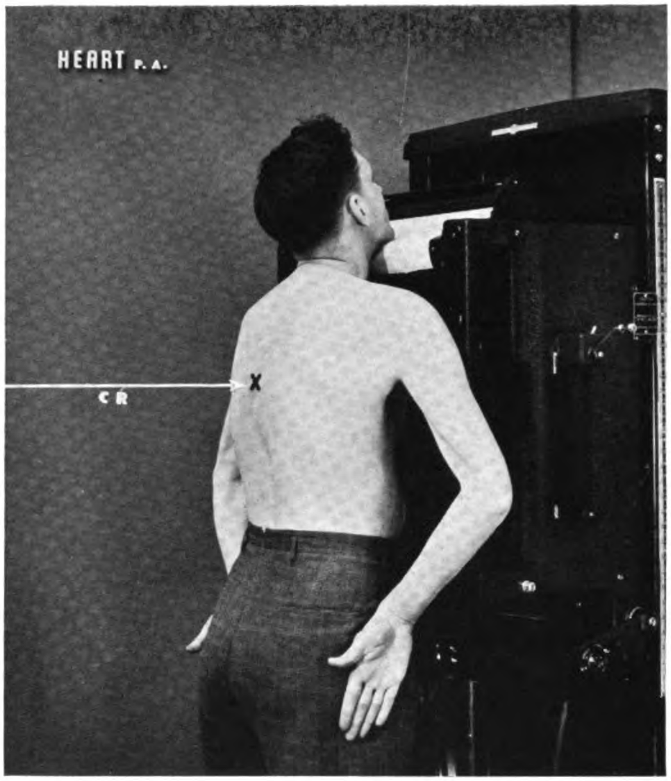


FIG. 344a

Heart, Postero-Anterior, Upright

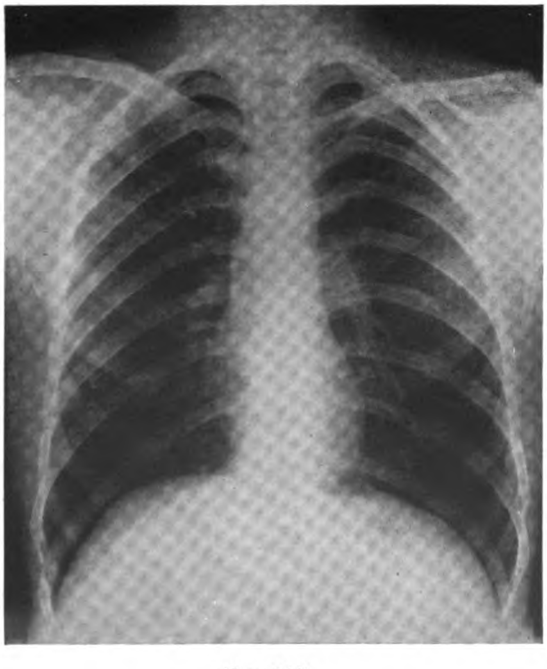


FIG. 344b

The patient is placed in the upright position facing the cassette holder. The median line of the body is placed over the centerline of the film. The chin is raised and rests on top of the cassette holder. The acromion processes should be positioned 2 to 3 inches below the upper corner of the cassette. The elbows are flexed with the back of the hands resting on the hips and the shoulders brought forward as far as possible. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 10 milliampere-seconds, 72-inch distance, 62 kilovolts peak

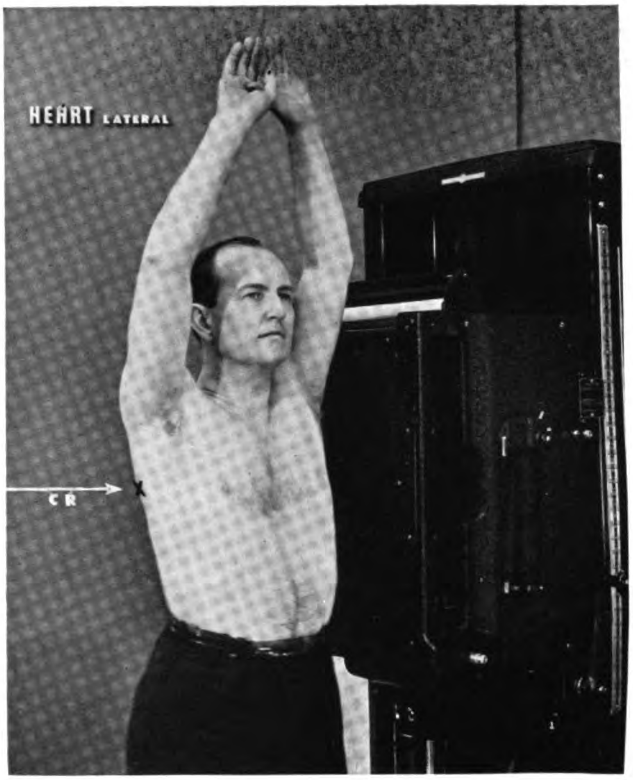


FIG. 345a

Heart, Lateral, Upright

Ordinarily the left side of the patient is placed next to the film. With the patient in the upright position, the arms are extended over the head, and the side of the body is placed in contact with the cassette holder. The cassette holder is adjusted to the same height as used for the postero-anterior heart. A point on the side of the body, midway between the sternum and the tips of the spinous processes is centered to the centerline of the film. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—30 centimeters. This thickness is measured at full inspiration
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- A cone is recommended for this part
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 20 milliampere-seconds, 40-inch distance, 66 kilovolts peak

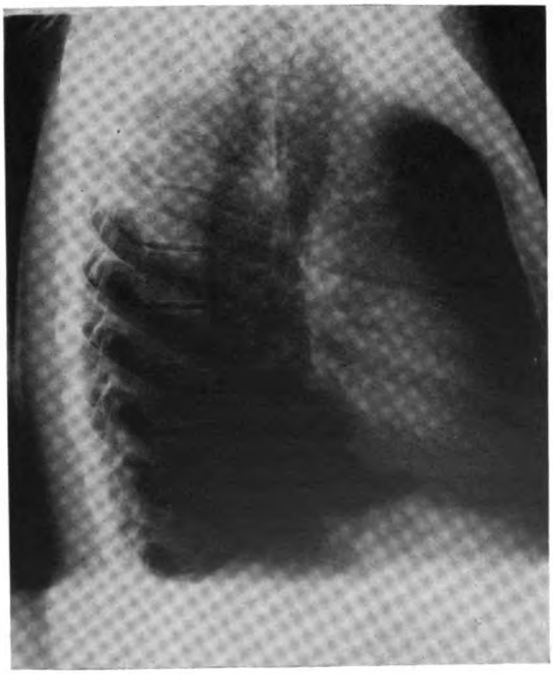


FIG. 345b

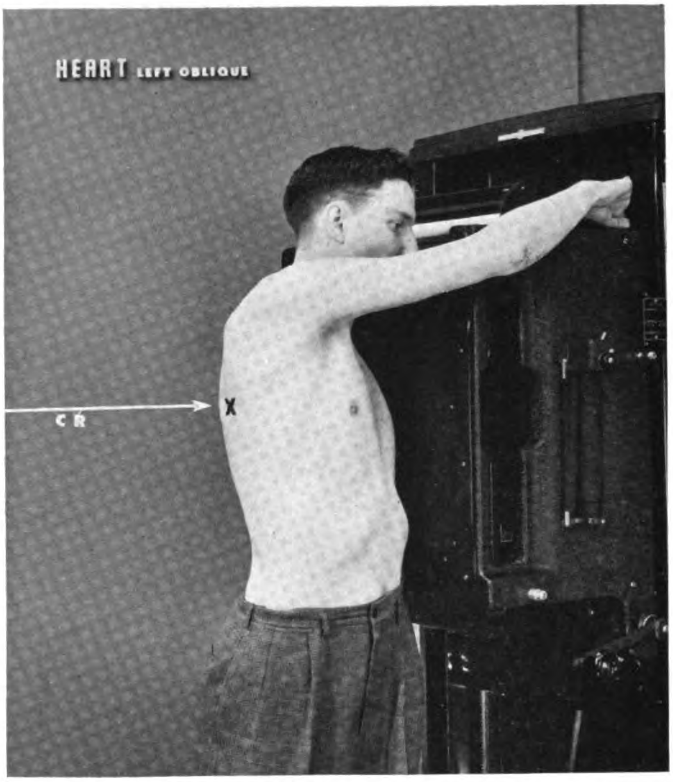


FIG. 346a

Heart, Left Oblique, Upright

The patient is placed in the lateral position, left side against the cassette holder. The cassette holder is adjusted to the same height as for the postero-anterior heart. The shoulders are turned forward as far as possible without turning the hips, which remain at right angles to the plane of the film. The left arm remains at the patient's side with the palm turned outward. The right arm is raised and rests on top of the cassette holder. The patient's chest is centered to the film. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—26 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 20 milliampere-seconds, 72-inch distance, 62 kilovolts peak

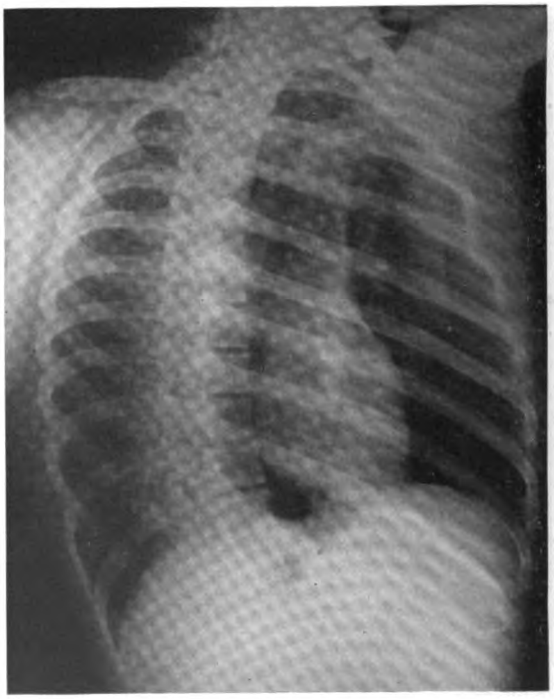


FIG. 346b

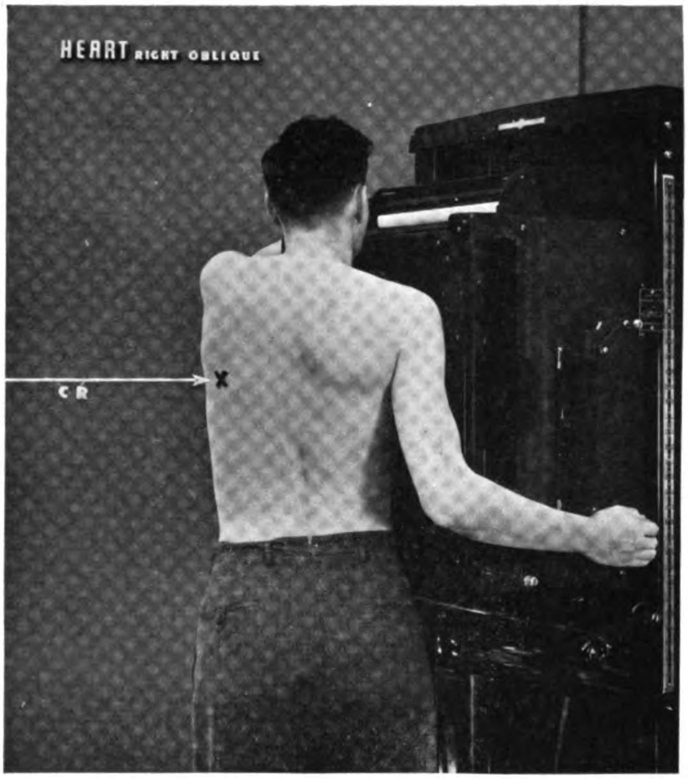


FIG. 347a

Heart, Right Oblique, Upright

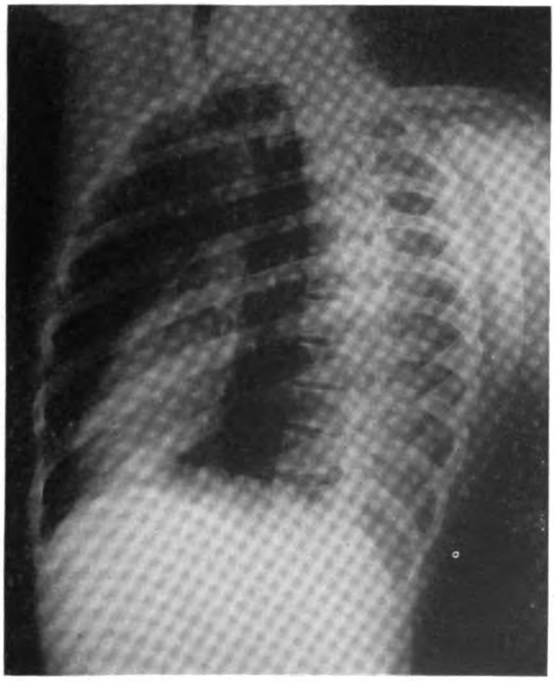


FIG. 347b

The patient is placed in the lateral position with the right side of the chest against the cassette holder. The cassette holder is adjusted to the same height as used for the postero-anterior heart. The shoulders are turned forward as far as possible without turning the hips, which remain at right angles to the plane of the film. The right hand grasps the side of the cassette holder and the left arm is raised and rests on top of the cassette holder. The patient's chest is centered to the film. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—26 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- The patient is asked to take in a deep breath and stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, without Potter-Bucky diaphragm, 20 milliampere-seconds, 72-inch distance, 62 kilovolts peak

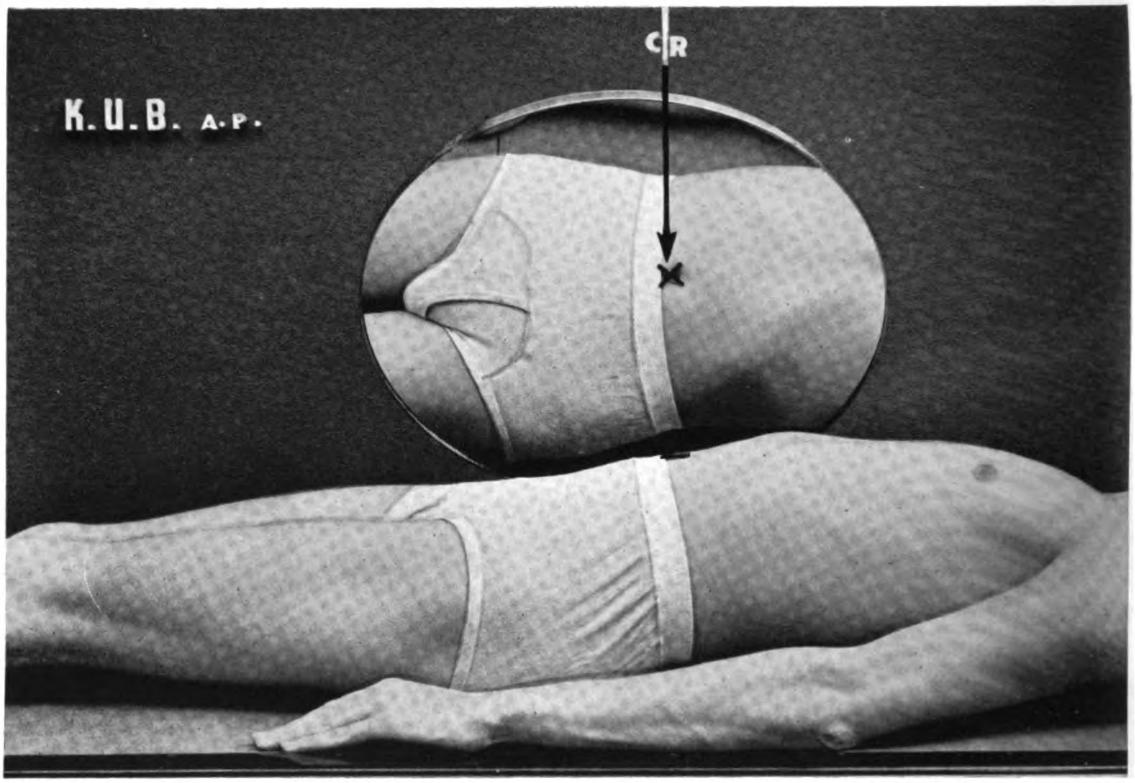


Fig. 348a

Kidneys, Ureters, Urinary Bladder (K.U.B.), Antero-Posterior

The patient is placed on the table in the supine position with the arms at the sides. The median line of the body is located over the table center-line. From the side of the table the film is centered to a point on the median line halfway between the inferior tip of the xyphoid process and a line through the anterior superior iliac spines. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17, long dimension of the film lengthwise the patient
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters. The measurement is made without compression band or compression bladder
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm,

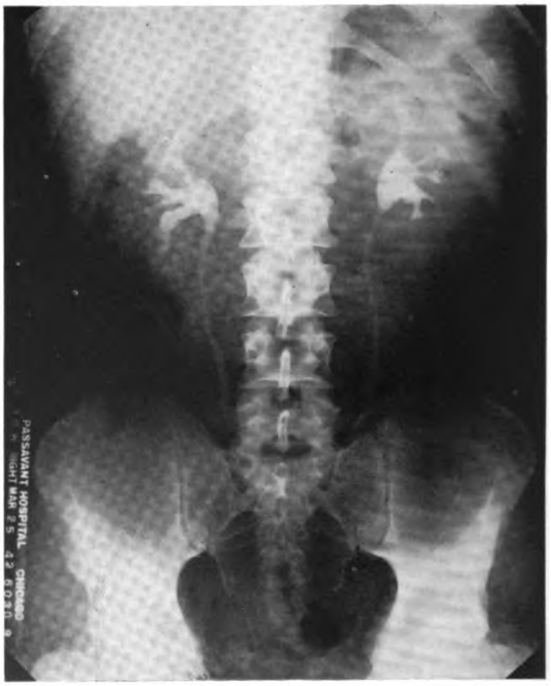


Fig. 348b

200 milliampere-seconds, 40-inch distance, 54 kilovolts peak

Courtesy of James T. Case, M.D., Passavant Hospital, Chicago

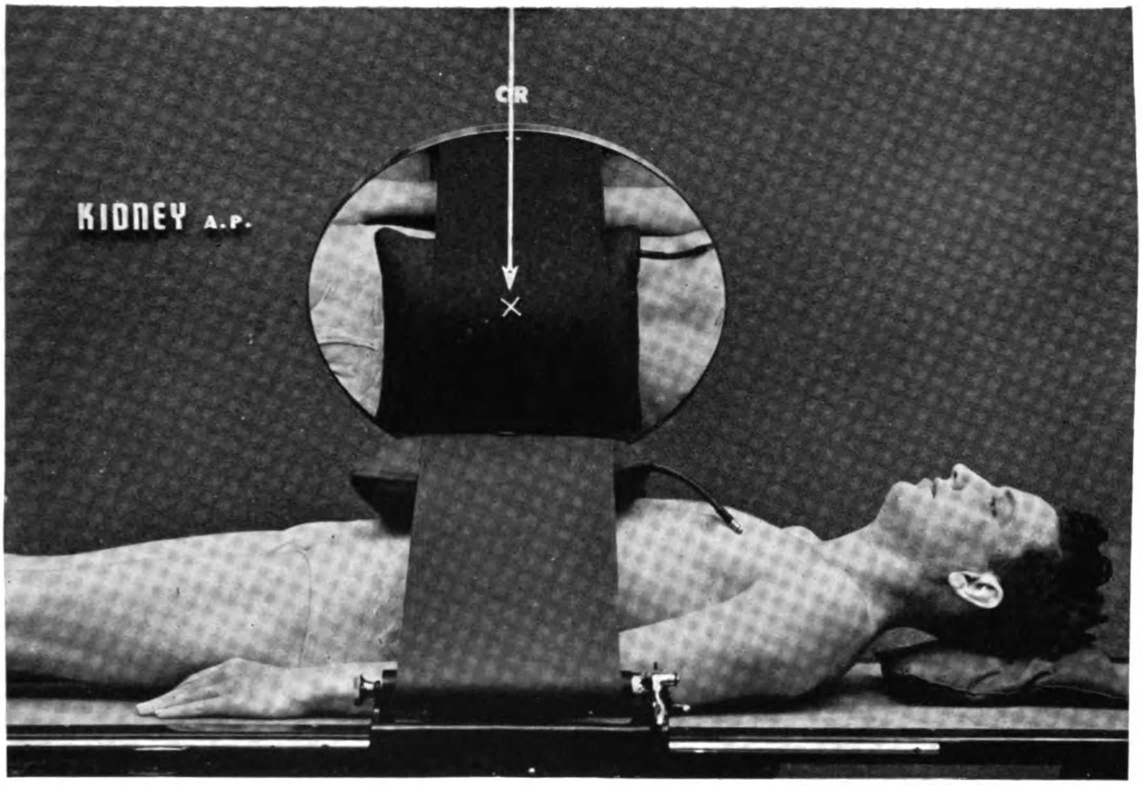


FIG. 349a

Kidney, Antero-Posterior

The patient is placed in the supine position with the arms at the sides and with the median line over the table centerline. From the side of the table the film is centered to the arch of the ribs. The central ray is directed to the center of the film. Compression is recommended.

PROCEDURE

- Size of film employed—usually 14 by 17, long dimension of the film lengthwise the body
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters. This measurement is made with the compression band and compression bladder in position
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 54 kilovolts peak

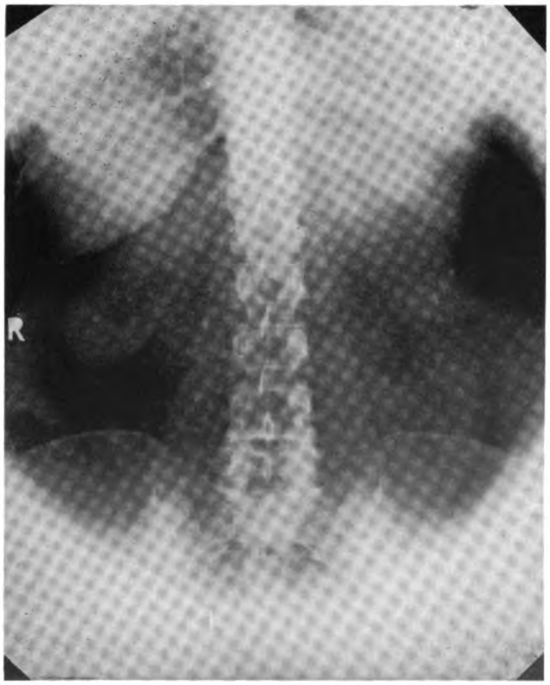


FIG. 349b

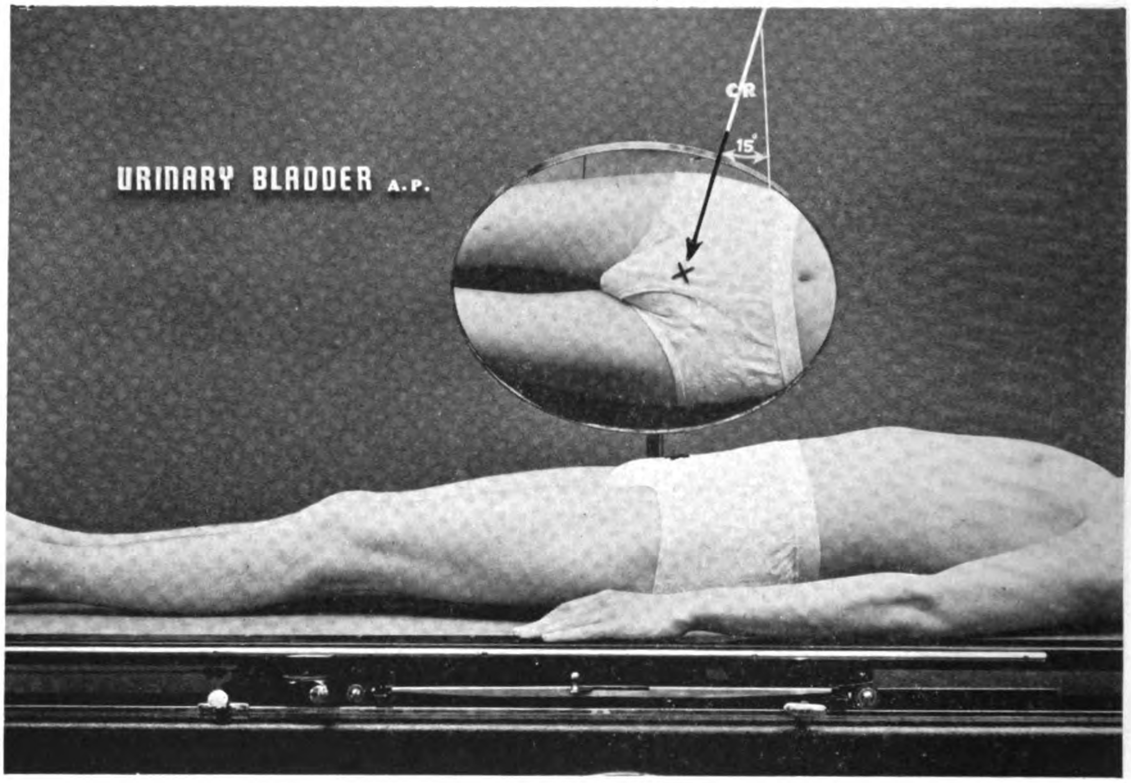


FIG. 350a

Urinary Bladder, Antero-Posterior

The patient is placed in the supine position with the arms at the side and with the median line over the table centerline. The tube is tilted 15 degrees toward the patient's feet and the central ray is directed to the superior border of the pubic symphysis. The film is centered to the central ray.

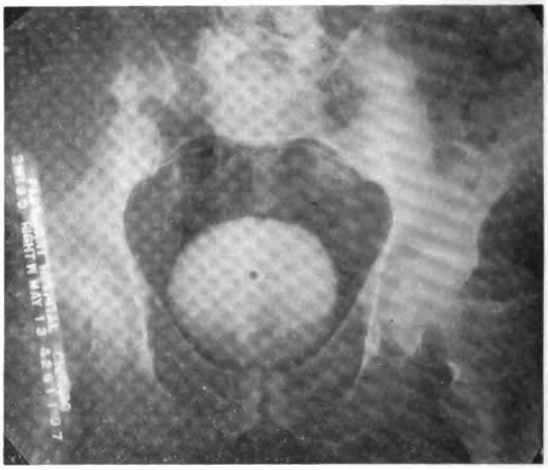


FIG. 350b

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 60 kilovolts peak

Courtesy of James T. Case, M.D., Passavant Hospital, Chicago

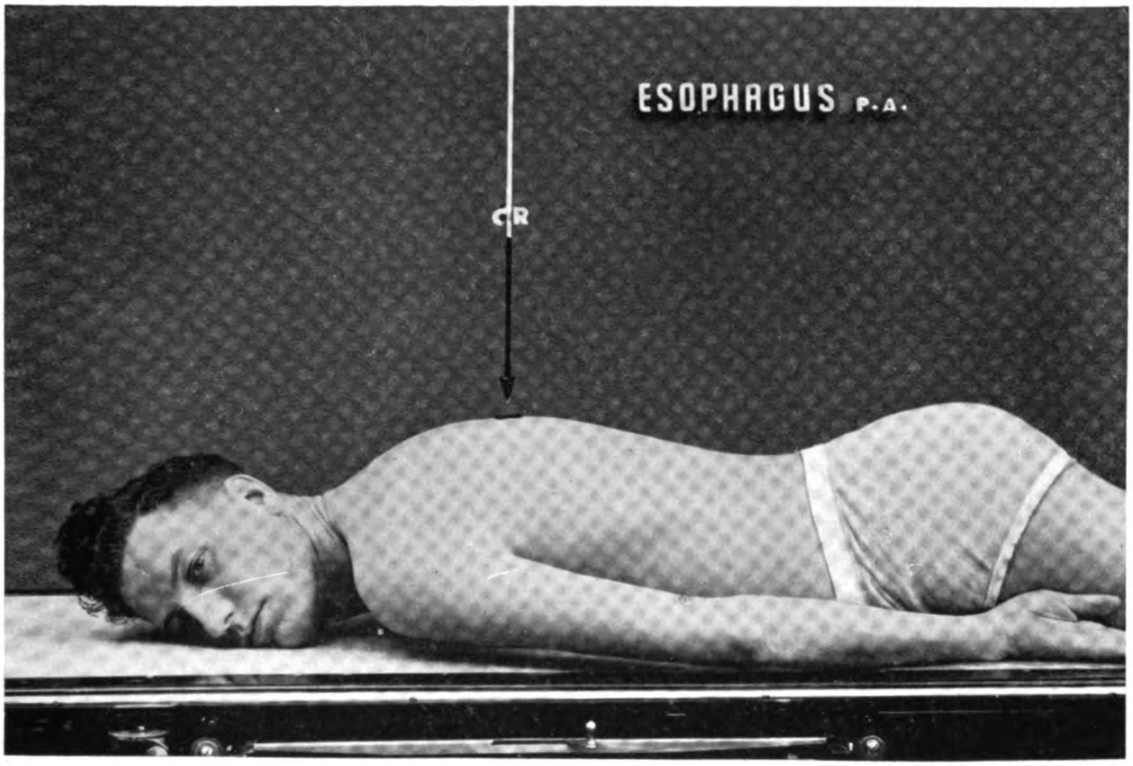


FIG. 351a

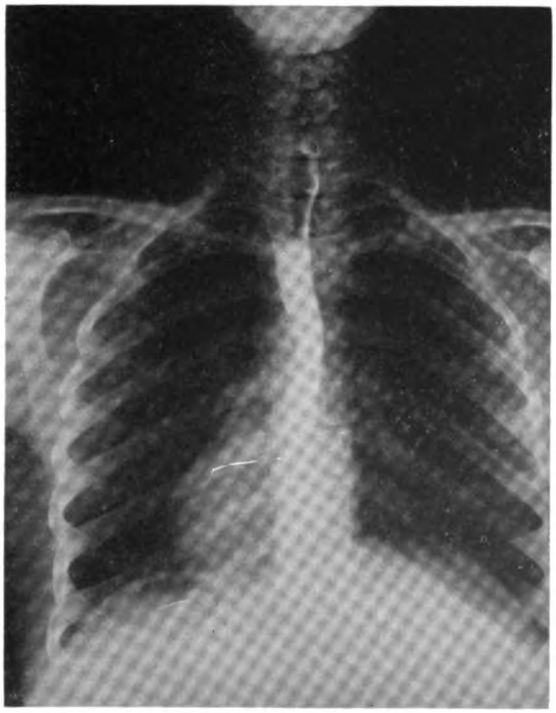


FIG. 351b

Esophagus, Postero-Anterior

The patient is placed in the prone position with the median line over the table centerline. From the side of the table the film is centered to a point halfway between the thyroid cartilage, or Adam's apple, and the lower tip of the xyphoid process. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17, long dimension of the film lengthwise the body
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—18 centimeters. This measurement is made at the upper margin of the sternum
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 62 kilovolts peak

Courtesy of James T. Case, M.D., Passavant Hospital, Chicago

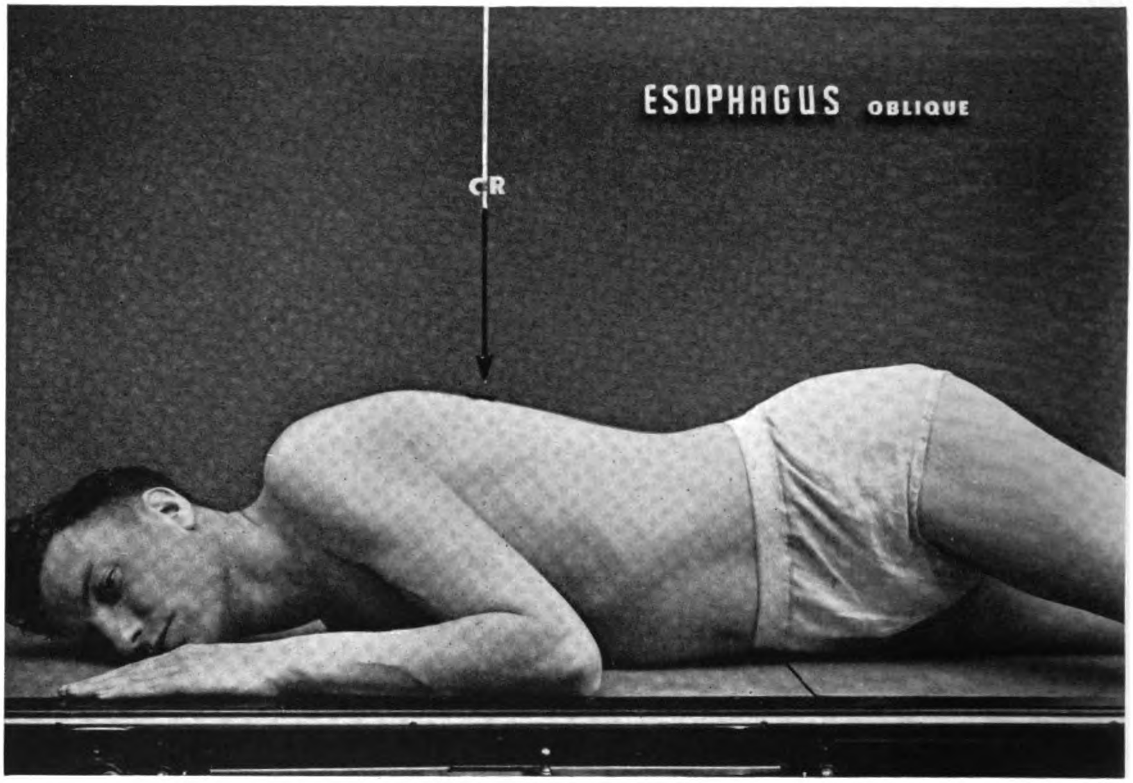


FIG. 352a

Esophagus, Oblique

The patient is placed in the postero-anterior oblique position. The spine is located to the immediate rear of the table centerline. From the side of the table the film is centered to a point halfway between the thyroid cartilage, or Adam's apple, and the lower tip of the xyphoid process. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17, long dimension of film lengthwise the body
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—22 centimeters. The measurement is made at the upper margin of the sternum
- Average variation in kilovolts peak minimum to maximum thickness for this part—18 kilovolts peak with Parspeed screens
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 62 kilovolts peak

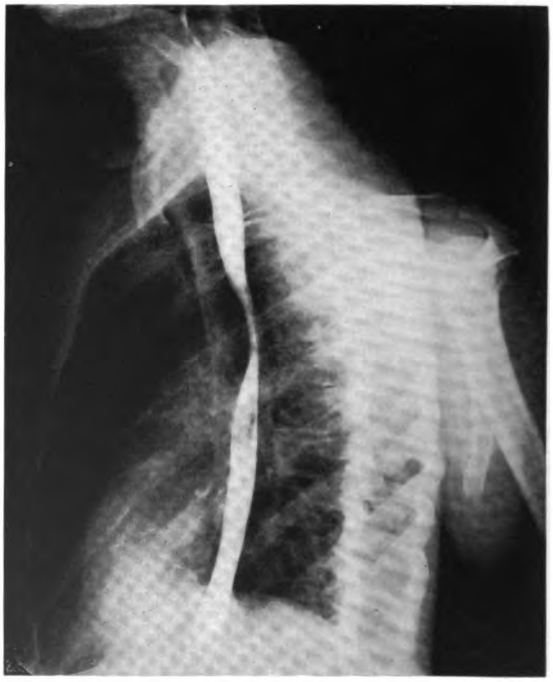


FIG. 352b

Courtesy of James T. Case, M.D., Passavant Hospital, Chicago

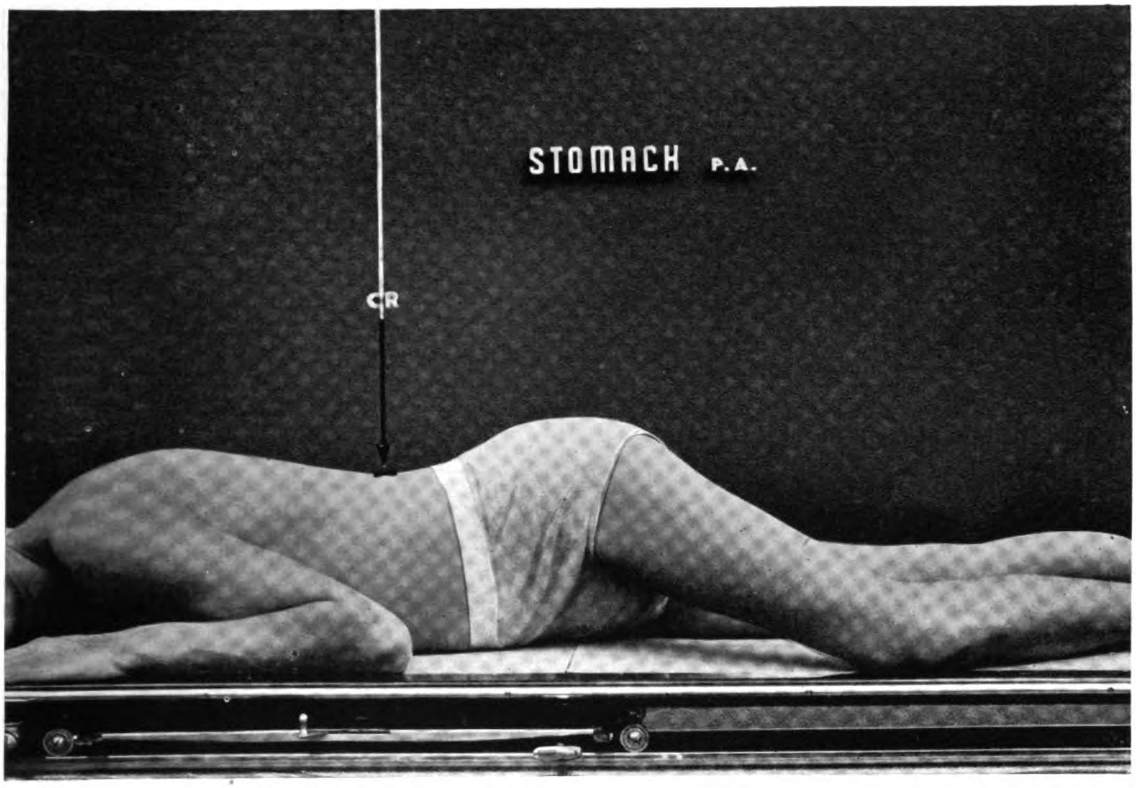


FIG. 353a

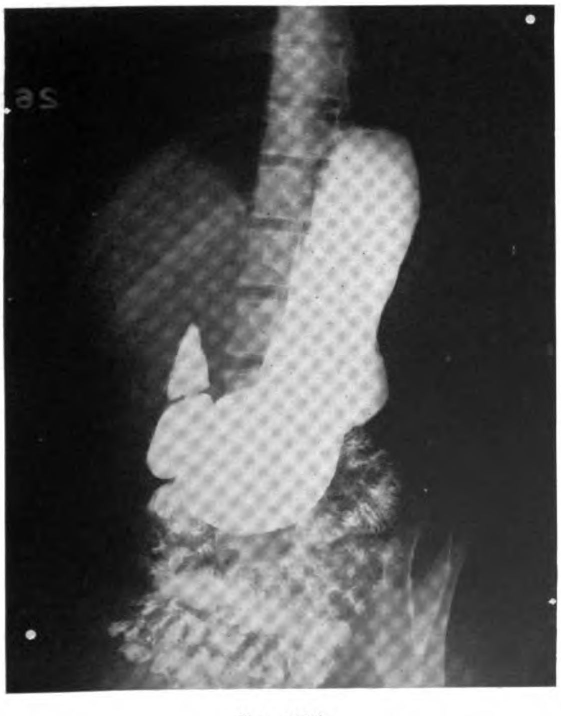


FIG. 353b

Courtesy of James T. Case, M.D., Passavant Hospital, Chicago

Stomach, Postero-Anterior

The patient is placed in the prone position. The left arm is flexed, and the left leg flexed to prevent spine pressure. The spine is located to the immediate rear of the table centerline. The film is centered to the arch of the ribs from the side of the table. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—21 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 70 kilovolts peak

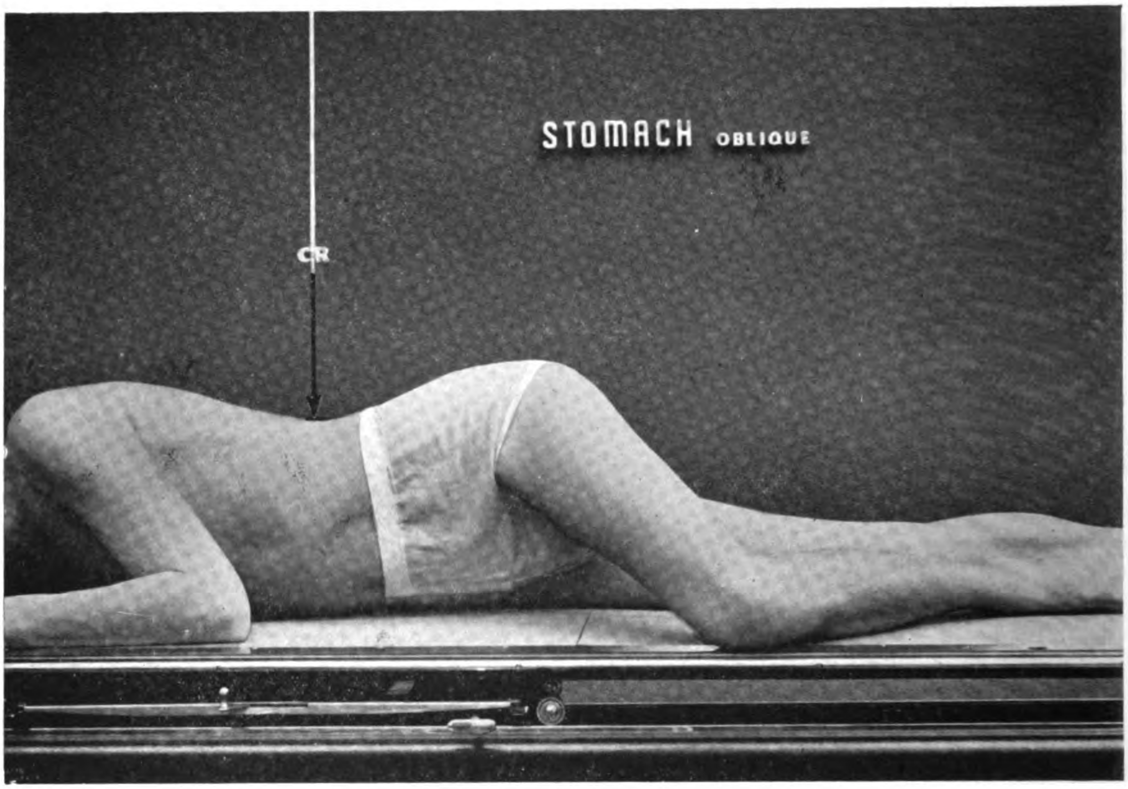


FIG. 354a

Stomach, Oblique

The patient is placed in the postero-anterior oblique position. The spine is placed to the immediate rear of the table centerline. The film is centered to the arch of the ribs from the side of the table. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—25 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—21 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 50 milliampere-seconds, 30-inch distance, 82 kilovolts peak

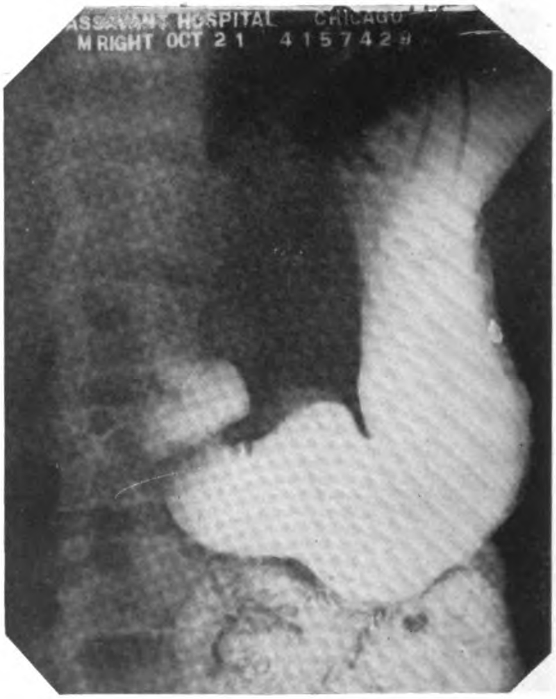


FIG. 354b

Courtesy of James T. Case, M.D., Passavant Hospital, Chicago

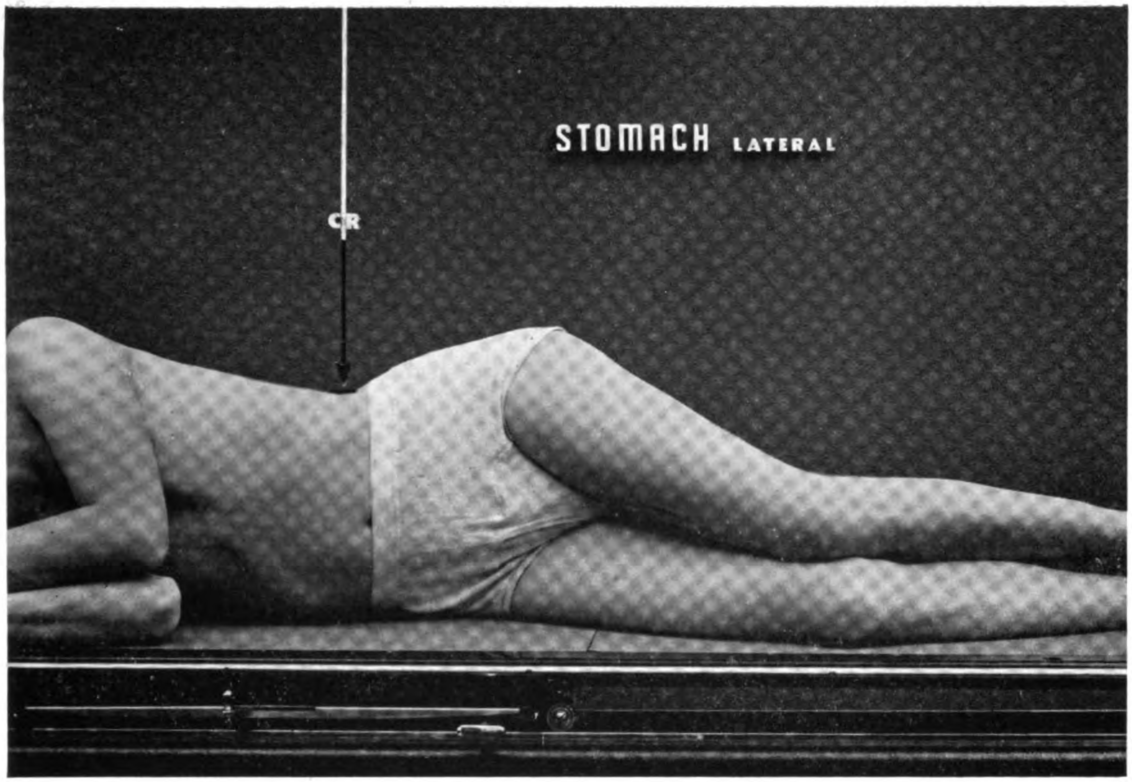


FIG. 355a

Stomach, Lateral

The patient is placed on the table in the lateral position. The spine is located to the immediate rear of the table centerline. The film is centered to the arch of the ribs from the side of the table. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 10 by 12
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—28 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—21 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 78 kilovolts peak

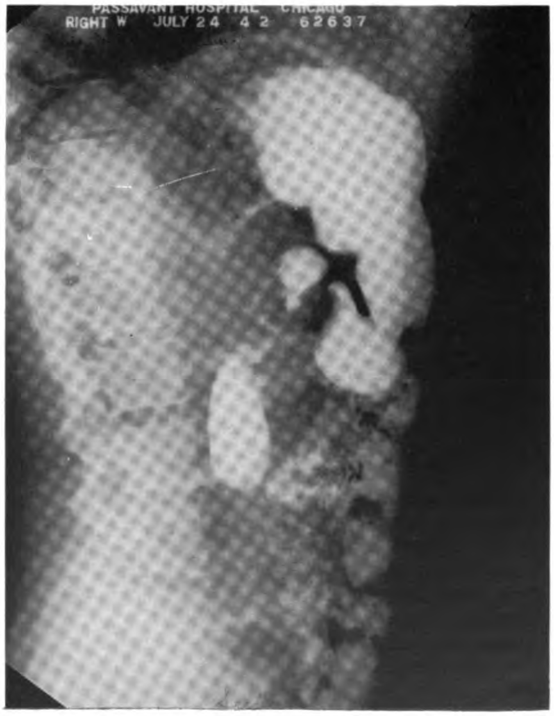


FIG. 355b

Courtesy of James T. Case, M.D., Passavant Hospital, Chicago

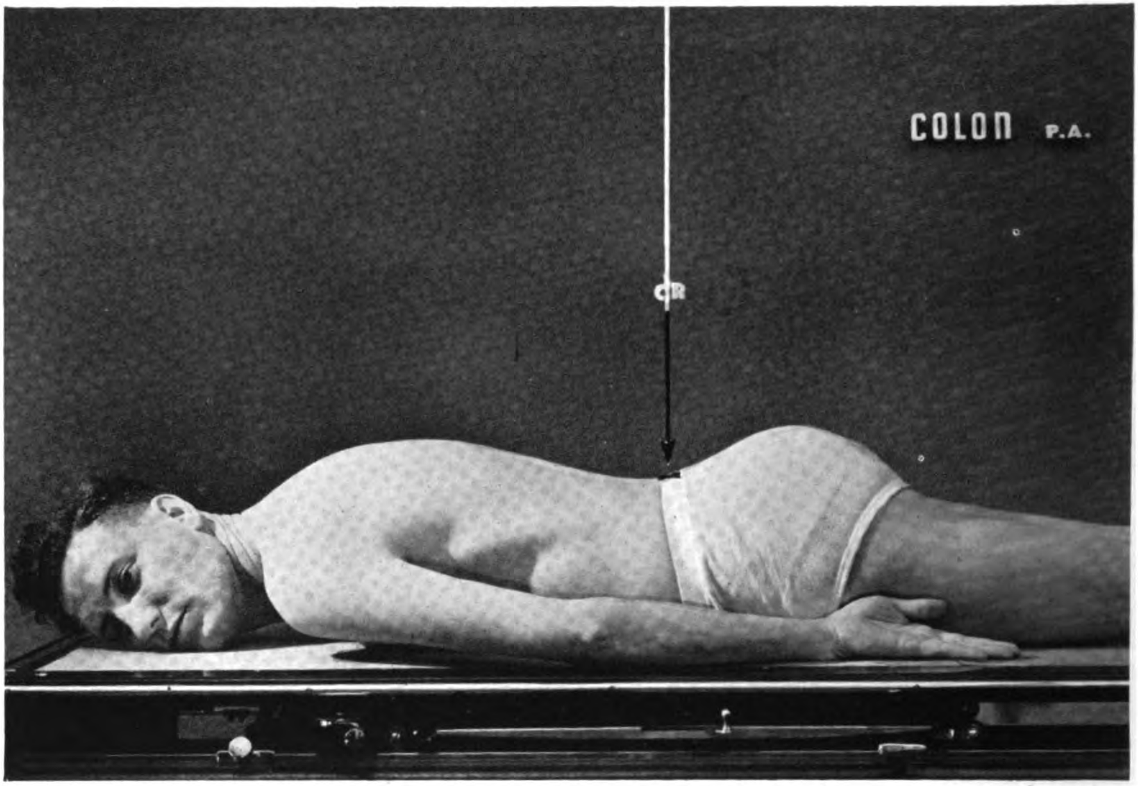


FIG. 356a

Colon, Postero-Anterior

The patient is placed on the table in the prone position with the median line of the body over the table centerline, and with the arms at the side of the body. From the side of the table the film is centered to the crest of the ilium. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17, long dimension of the film lengthwise the body
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—21 kilovolts peak with Parspeed screens
- The patient is asked to stop breathing during the exposure
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 40-inch distance, 66 kilovolts peak

Courtesy of James T. Case, M.D., Passavant Hospital, Chicago

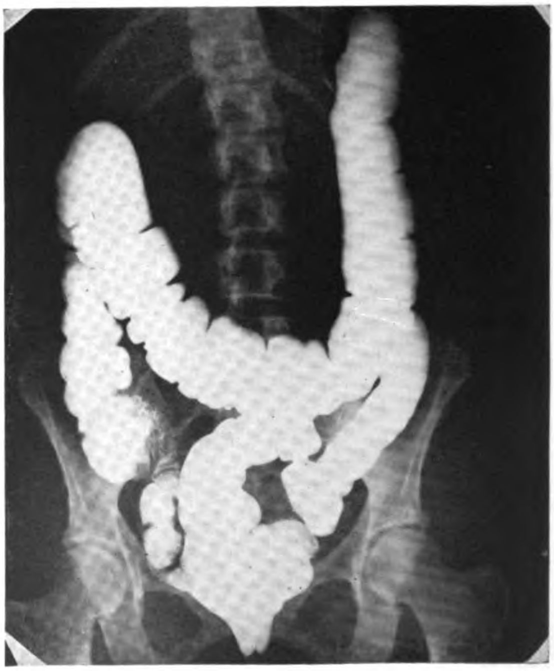


FIG. 356b

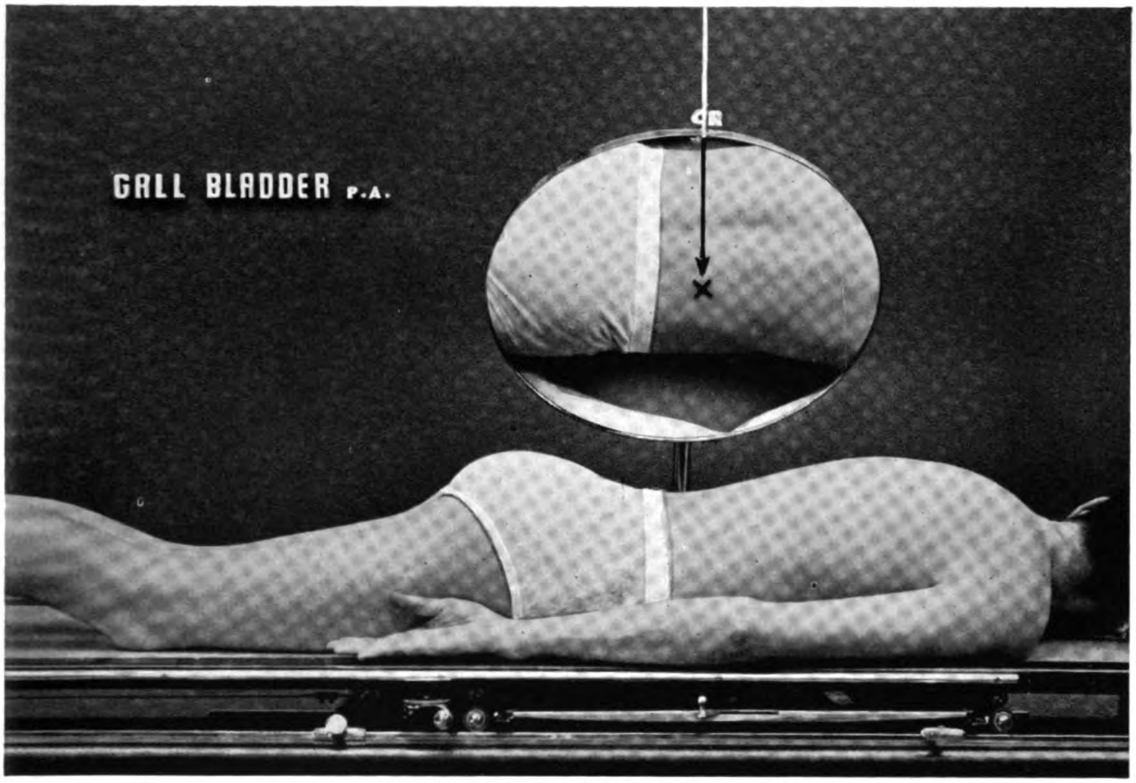
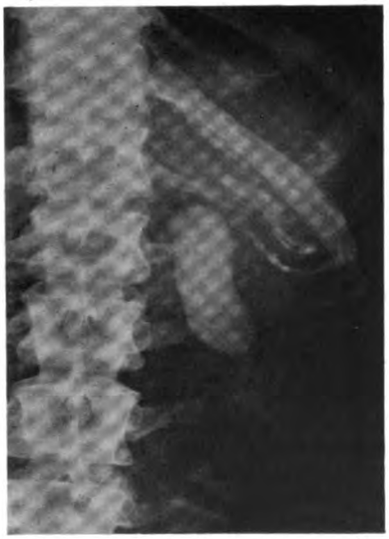


FIG. 357a



Gall Bladder

The patient is placed in the prone position with the arms at the sides. The center of the lower right anterior rib is centered to the film. The central ray is directed to the center of the film.

For the oblique view, the patient is placed in the postero-anterior oblique position with the spine to the immediate rear of the table centerline. The film is centered to the lower right anterior rib and the central ray is directed to the center of the film.

For the lateral view, the patient is placed in the lateral position with the spine to the immediate rear of the table centerline. The film is centered to the lower right anterior rib and the central ray is directed to the center of the film.

For the upright views, the central ray is directed to a point approximately 2 inches above the tip of the iliac crest nearer the tube.

FIG. 357b

PROCEDURE

- Size of film employed—usually 8 by 10
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 2 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—20 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—21 kilovolts peak with Parspeed screens
- A cone is recommended for this part
- The patient is asked to stop breathing during the exposure

- **Suggested starting technic:**

  Postero-Anterior view: With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 60 kilovolts peak

  Oblique view: With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 72 kilovolts peak

  Lateral view: With Parspeed screens, with Potter-Bucky diaphragm, 100 milliampere-seconds, 30-inch distance, 76 kilovolts peak

  Upright views: Increase approximately 6 kilovolts peak

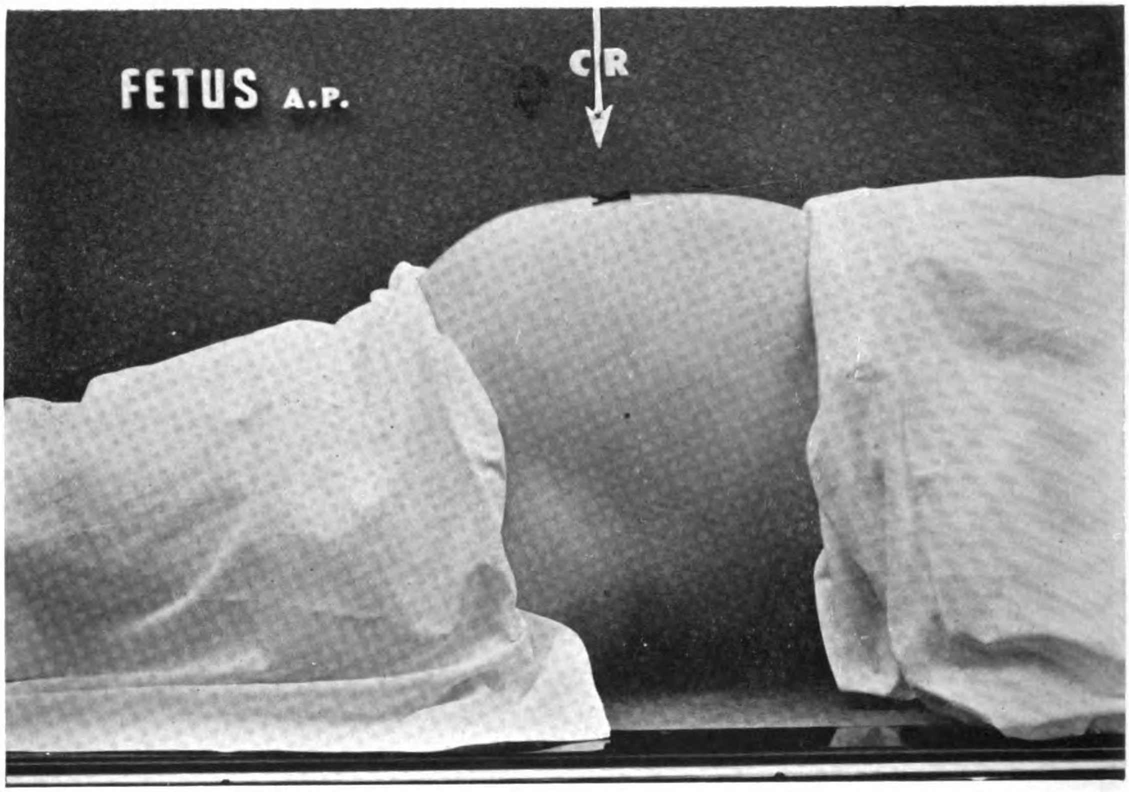


FIG. 358a

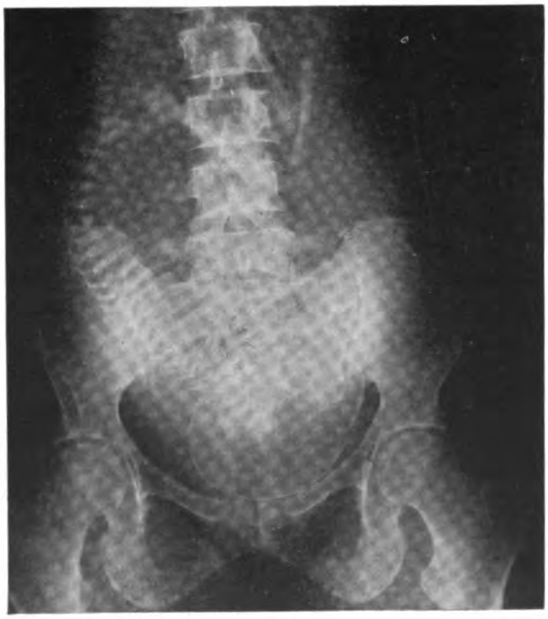


FIG. 358b

Fetus, Antero-Posterior

The patient is placed in the supine position with the median line over the table centerline. From the side, the film is centered to the crest of the ilium. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—28 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 78 kilovolts peak

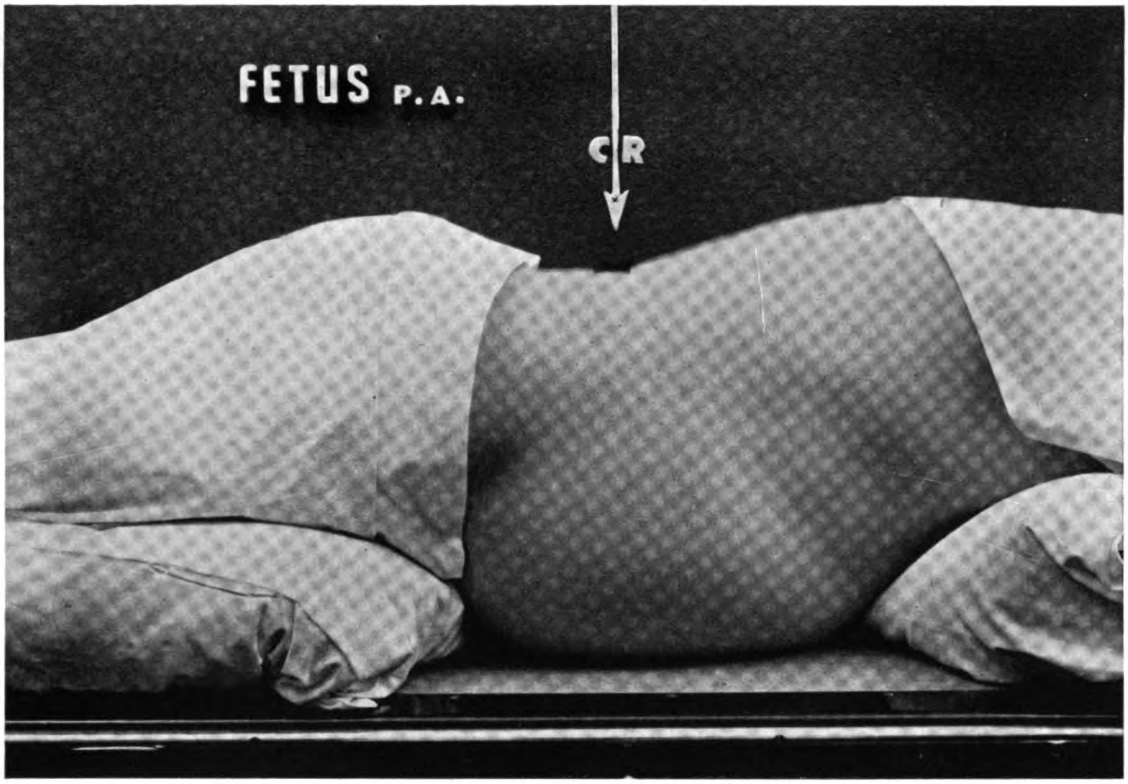


FIG. 359a

Fetus, Postero-Anterior

The patient is placed in the prone position with a pillow under the hips and chest for support. The median line of the body is located over the table centerline. From the side of the table the film is centered to the crest of the ilium. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—25 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 72 kilovolts peak

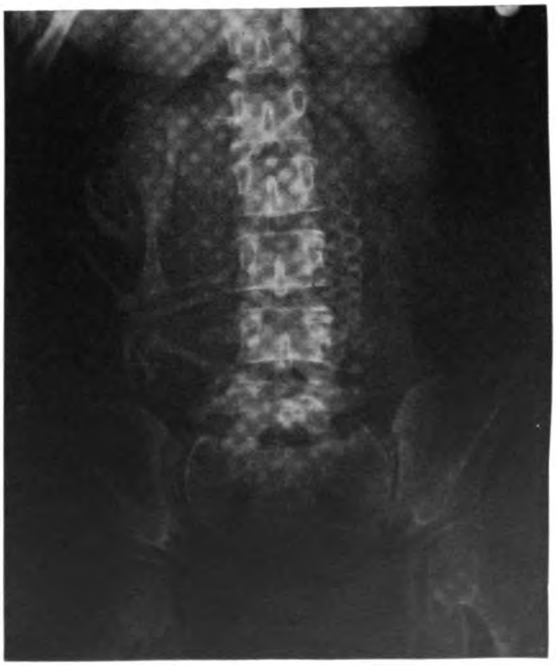


FIG. 359b

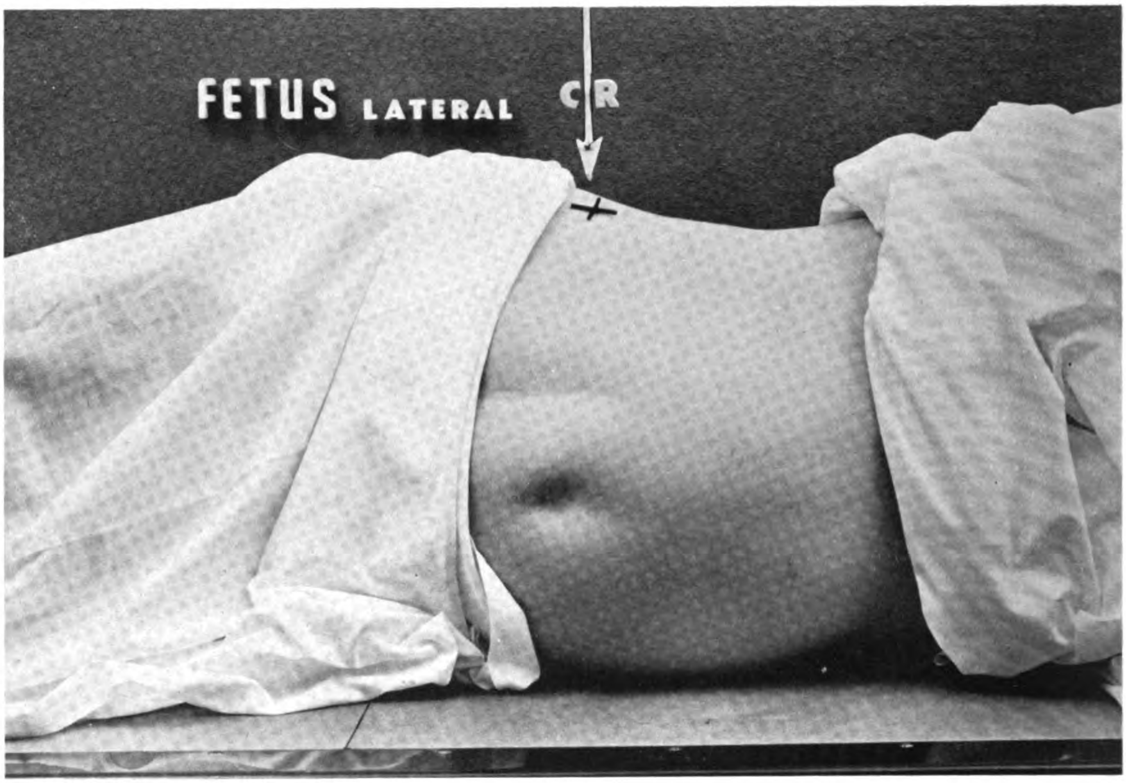


FIG. 360a

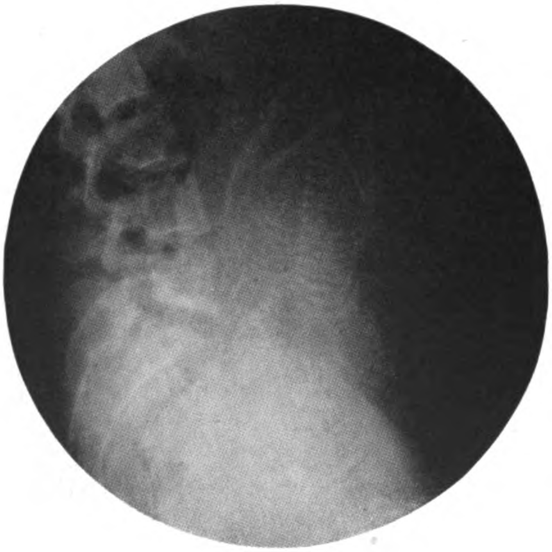


FIG. 360b

Fetus, Lateral

The patient is placed on the table in the lateral position. The center of the side of the body is placed over the table centerline. From the side, the film is centered to the crest of the ilium. The central ray is directed to the center of the film.

PROCEDURE

- Size of film employed—usually 14 by 17
- Variation in kilovolts peak per centimeter thickness with Parspeed screens—approximately 3 kilovolts peak
- Centimeter thickness of part used in preparation of this chart—30 centimeters
- Average variation in kilovolts peak minimum to maximum thickness for this part—20 kilovolts peak with Parspeed screens
- **Suggested starting technic:**
  With Parspeed screens, with Potter-Bucky diaphragm, 200 milliampere-seconds, 40-inch distance, 82 kilovolts peak

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THE DENTAL technical procedure described in this chapter refers to dental radiography in the general medical x-ray laboratory. Because of the wide variation in the structure of the anatomical parts involved, it is considered almost impossible to give definite standard positions for such work. The positions illustrated and the degree of angulation shown should therefore be considered as a starting point based on what might be considered the average mouth.

There are certain basic factors involved in dental technical procedure, however, which are universally applicable. A thorough understanding of those factors which bring about the desired end result will enable the operator to systematically vary the procedure in order to bring about a definite result.

Angulation

The first and probably most difficult factor to duplicate consistently is angulation. Angulation refers to the alignment of the *tube, object, and film. The alignment is considered correct when the minimum of distortion of the object is obtained.*

The rule for obtaining the proper alignment of the tube, object, and film, is as follows: bisect the angle made by the plane of the tooth and the plane of the film and direct the central ray so that it strikes at right angles or perpendicular to this bisecting plane.

Figure 361A is a diagram showing the proper alignment of the tube, object, and film, using the upper jaw as the subject; Figure 361B is a radiograph taken in this manner.

Using the same region, if the angle of the tube is too great, that is, if the plane of the tube more nearly approaches the plane of the film, fore-shortening of the teeth will result as is shown in Figure 362 A. Figure 362 B is a radiograph illustrating this fore-shortening.

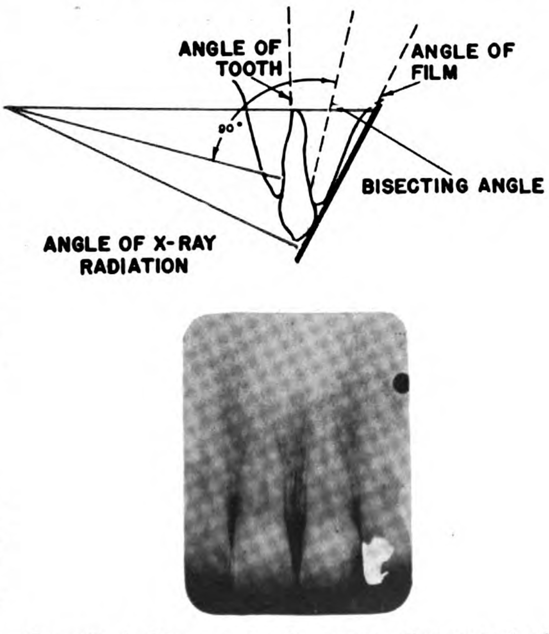


FIG. 361. A. Diagram showing proper alignment of tube. B. Radiograph showing result of proper alignment of tube.

Again using the same region, if the angle of the tube is insufficient, that is, if the plane of the tube more nearly approaches the plane of the tooth, elongation of the teeth will result, as in Figure 363A. Figure 363B is a radiograph taken under these conditions.

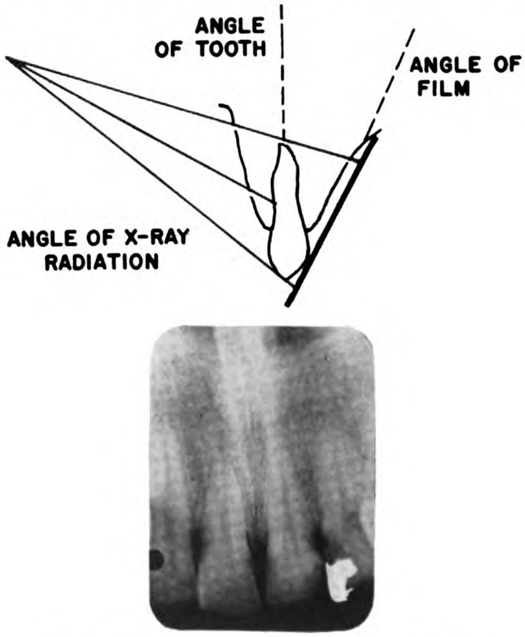


FIG. 362. A. Diagram showing fore-shortening.

B. Radiograph showing result of fore-shortening.

In making radiographs of teeth in the *upper jaw,* the tube at all times is placed so that the angle of the central ray is above the occlusal plane.

In the *lower jaw,* the tube is placed so that the angle of the ray is below the occlusal plane, with the exception of radiographs of the lower molars, wherein many instances the plane of the tooth and film are almost parallel. In this case, directing the central ray at right angles to the plane of the tooth and film gives the minimum of distortion, as in Figure 364A. Figure 364B is the end result.

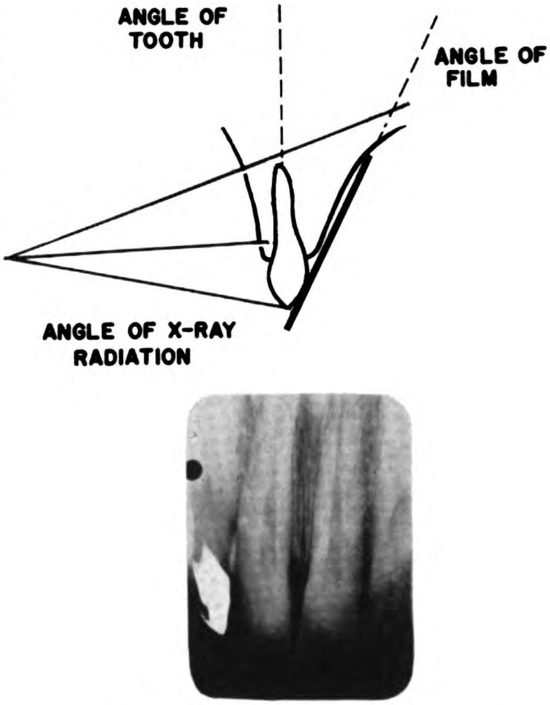


FIG. 363. A. Diagram showing elongation.

B. Radiograph showing result of elongation.

The above takes into consideration the results of variations in angles up and down the head only. There is another angle which may interfere materially and which is just as important from the standpoint of distortion. That is the angle crosswise the head. For practically all standard dental positions, the plane of the film and the plane of the tube should be parallel. There may be times when the operator will intentionally rotate forward or backward, as in the case of multi-rooted teeth in order to bring out a particular root. However, it will be found that this rotation forward or backward produces an overlapping of the shadow of one tooth on the one

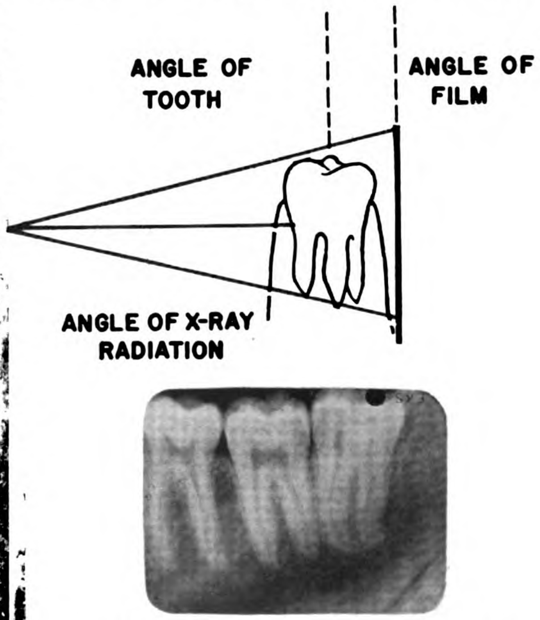


FIG. 364. A. Diagram showing correct angulation.

B. Radiograph showing result of correct angulation.

next to it. This occurs the same way in either the upper or lower jaw.

Figures 365A and 366A show the result of proper crosswise alignment and improper crosswise alignment. Figures 365B and 366B are the radiographic results.

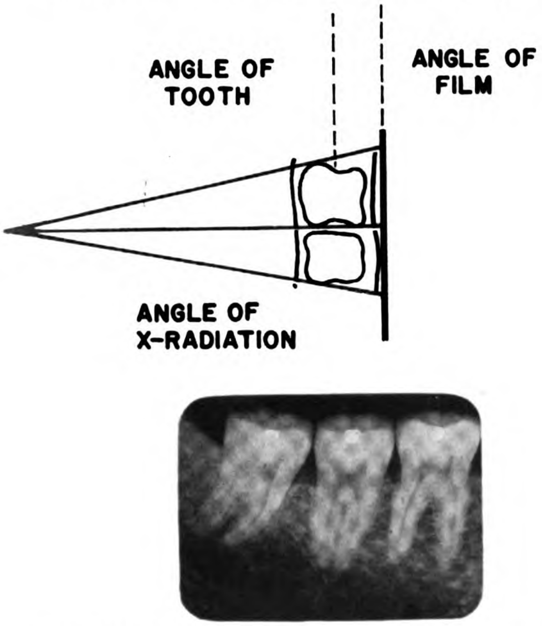


Fig. 365. A. Diagram showing proper crosswise alignment.

B. Radiograph showing result of proper crosswise alignment.

Full Mouth Examination

The ideal dental radiographic examination of an adult patient might include as many as thirty-two individual films, the object being to radiograph each tooth on a separate film. From a practical standpoint, however, it is not necessary to use thirty-two films because, in most areas, more than one tooth can be satisfactorily shown on a film, and if a total of sixteen films, Figure 367, are used and the patient and central ray positioned as outlined, from two to four teeth, depending on the region being radiographed, will usually be satisfactorily shown. With this procedure there is also the advantage of obtaining more than one view of a particular tooth.

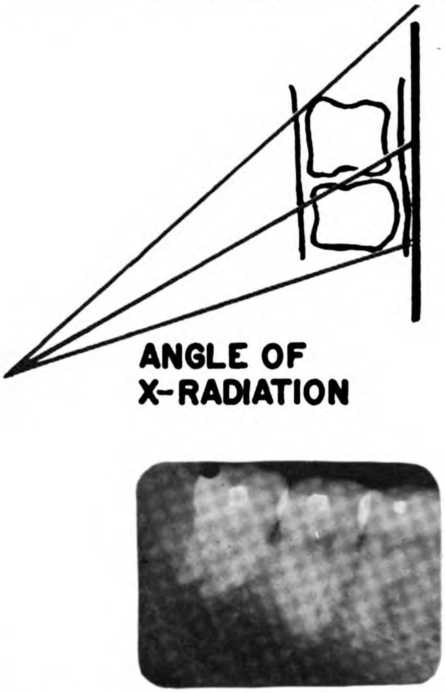


Fig. 366. A. Diagram showing improper crosswise alignment.

B. Radiograph showing result of improper crosswise alignment.

The following list depicts those teeth for which the particular exposure is being made, and also the number of teeth which are usually satisfactorily shown on the film. Those underlined show a profile image, the others a diagonal image. The last column gives the positions of the film in the patient's mouth.

Film		No. of Teeth on Each Film	Position of Film in Mouth
	UPPER JAW		
No. 1	*Central Incisors*	2	Vertical
No. 2	*Left Central Incisor, Lateral Incisor,* and Cuspid	3	Vertical
No. 3	Left Lateral Incisor, *Cuspid,* and Bicuspid	3	Vertical
No. 4	*Left Cuspid, Bicuspids,* and *1st Molar*	4	Horizontal
No. 5	Left 1st, *2nd,* and *3rd Molars*	3	Horizontal
No. 6	Right *Central Incisor, Lateral Incisor,* and *Cuspid*	3	Vertical
No. 7	Right Lateral Incisor, *Cuspid,* and Bicuspid	3	Vertical
No. 8	*Right Cuspid, Bicuspids,* and *1st Molar*	4	Horizontal

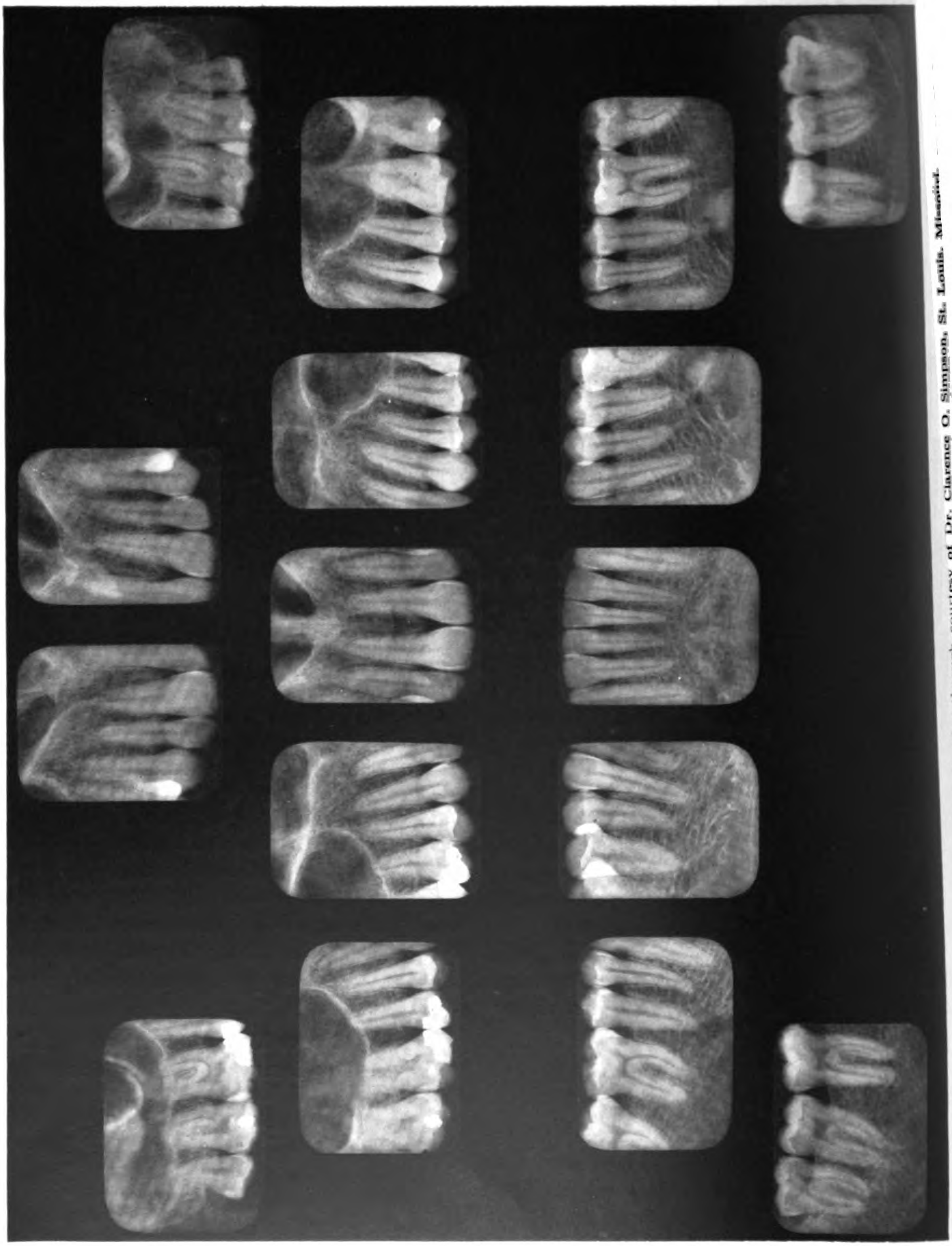


Fig. 165. 16-film full denture. Reproduction through courtesy of Dr. Clarence O. Simpson, St. Louis, Missouri.

		No. of Teeth on Each Film	Position of Film in Mouth
No. 9	Right 1st, *2nd,* and 3rd Molars	3	Horizontal
	LOWER JAW		
No. 10	*Central Incisors*	4	Vertical
No. 11	Lateral Incisor, *Left Cuspid,* and Bicuspid	3	Vertical
No. 12	Left Cuspid, *Bicuspids, 1st* and 2nd Molars	5	Horizontal
No. 13	Left 1st, *2nd,* and 3rd Molars	3	Horizontal
No. 14	Lateral Incisor, *Right Cuspid,* and Bicuspid	3	Vertical
No. 15	Right Cuspid, *Bicuspids, 1st* and 2nd Molars	5	Horizontal
No. 16	Right 1st, *2nd,* and 3rd Molars	3	Horizontal

In placing the film in the mouth, it is essential that it be far enough below or above the occlusal surface of the teeth, depending on whether the lower teeth or the upper teeth are being taken, in order that the apices of the roots will be on film.

The Use of Bite Blocks

As one of the greatest difficulties to deal with in dental work is motion of the film in the patient's mouth, the use of bite blocks, is recommended whenever practical. This reduces the danger of motion of the film to the minimum. Bite blocks also take care of pushing the film as low or as high in the mouth as possible as well as in placing the film in approximately the same place on most individuals. They also aid in reraying certain areas by permitting the operator to place the film in virtually the same position in the patient's mouth. Care must be taken also that the film remain straight in the patient's mouth. Curving the film to conform to the curve in the mouth causes distortion, particularly of the areas at each end or side of the film. Bite blocks tend to reduce curving to the minimum.

It is necessary, with certain patients, to either bend the corners of the film or curve it. If sixteen films are being employed for a full denture, curving of the films is not so important, because in general it will be possible to successfully radiograph two teeth despite some curvature.

All dental films are metal-backed. Care should therefore be taken that the back of the film is always away from the x-ray tube. Insert the film in the slot of the bite block and place the block between the occlusal surfaces, being sure that the film is in the desired position. Instruct the patient to bite on the block and not to move during the time of exposure. If bite blocks are not available or it is not desired to use them, the thumb or index finger of the patient is ordinarily used for holding the film in position. The patient should be carefully instructed as to the amount of pressure necessary to hold the film in position. Too much pressure has a tendency to make the film skid in the patient's mouth, and too little pressure has a similar effect. The left thumb or index finger is used for the right side of the mouth, and the right thumb or index finger is used for the left side of the mouth. The operator should make sure that the rest of the hand is not placed in such a position that it is between the film and the x-ray tube.

Position of the Patient

The position of the patient for dental work may be either supine, or upright. However, there is less danger of motion on the part of the patient while in the supine position, and inasmuch as the tube stand is nearly always attached to the table, it is considerably easier for the operator to duplicate angles.

With the patient placed in the supine position on the x-ray table, the head should be placed on a pad of sufficient thickness so that the occlusal plane shall be kept at right angles to the table top. Sandbags are quite convenient for this purpose. The tube should be placed squarely across the table with the tube supports parallel with the head end of the table. In general, it will be found much easier to rotate the patient's head instead of changing the tube. As the patient's head is rotated, care must be taken that the occlusal plane remains at right angles to the table top. This is much more important for the upper jaw than for the lower jaw. If the angles used are carefully noted, it becomes relatively easy to make additional films of the same area and to make desired variations in angles depending on the desires of the operator.

For the upper jaw it will be found that almost the same angle up and down the head is required for all the upper teeth. The variation is seldom over 25 degrees, especially if the head is laying as flat upon the table as possible and if the occlusal plane is at right angles to the table top.

If the teeth of the *upper jaw* are elongated, the tilt has not been sufficient and should be increased toward the feet. If the teeth are foreshortened, the tilt has been too great and should be decreased.

For the *lower jaw,* the position of the tube will necessarily have to be changed. For the lower incisors, the chin should be elevated as far as convenient so that the tube tilt may be as small as possible to obtain the correct angle.

If the teeth in the lower jaw are elongated, it is because the tilt toward the patient's head was not sufficient. If the teeth are fore-shortened, the tilt was too great.

The various factors used for general x-ray work are used for dental work, and the same rules regarding distortion, detail, contrast, and density should be followed.

Starting Procedure

It is exceedingly difficult to give a starting technic for dental radiography primarily because there is such a wide variation in the speed of dental films. The starting procedure given below, therefore, is based on what might be termed a dental film of medium speed.

The milliampere-second factor will vary, depending upon the apparatus and tube available.

Twenty-five to fifty milliampere-seconds at a distance of 25 to 28 inches may be used as a starting point. Of the two, 50 milliampere-seconds is preferable from the standpoint of average contrast.

The kilovolts peak value ordinarily is between 65 and 75 kilovolts peak.

If the time factor is constant, the kilovolts peak will vary from 8 to 12 kilovolts peak depending upon the region. Example: 65 kilovolts peak for the lower incisor region, 68 for the upper cuspid region, 71 kilovolts peak for the upper lateral incisor region, lower 1st and 2nd molar region and lower cuspid region, 73 kilovolts peak for upper central incisors, upper first molar, and 76 kilovolts peak for upper second molar region.

As is the case in general x-ray work, if insufficient contrast results from the above procedure, the kilovolts peak value must be reduced and the milliampere-second value increased.

Under average conditions, the difference in voltage necessary between an individual having a thin face and one having a fat or relatively heavy face is no greater than 12 or possibly 15 kilovolts peak in extreme cases. For example, if 70 kilovolts peak is required for a thin-faced individual, it might require 12 to 15 kilovolts peak more for the same area on an individual with a fleshy or heavy face.

Cones of the proper size must be used for dental work. They are usually 2½ to 3 inches in diameter by 10 inches long, or 2½ to 3 inches by 7 inches long. The smaller opening not only allows for a more positive centering, but also tends to protect the face of the patient from unnecessary exposure. It must be borne in mind that for a full denture, considerable overlapping of the area results. Limiting this area with as small a cone as possible will aid materially in reducing this exposure. One-half to one millimeter of aluminum or its equivalent should always be used as a filter.

Unlike general medical radiography, many operators choose to vary the time of exposure for the various areas in the individual mouth. In other words, for a thin-faced individual, the kilovolts peak may be established at a given point, such as 65 kilovolts peak, and the time of exposure varied depending upon the part of the mouth being taken. For the fleshy or heavy-faced individual, a higher voltage is used and again the time of exposure varied as between the various areas of the mouth. The following are examples:

70 kilovolts peak, 25-inch distance,
20 milliamperes

Lower Incisor region	3 seconds
Upper Cuspid region	3½ seconds
Upper Lateral Incisor region	4½ seconds
Lower 1st and 2nd molar region	4½ seconds
Lower Cuspid region	4½ seconds
Upper Central region	5 seconds
Upper 1st molar region	5 seconds
Upper 2nd molar region	6 seconds

For inter-proximal (Bite-Wing) examination, follow the technic as given on the film box.

In general, for this type of work there is little to choose between the two systems of procedure.

It is well for the operator to have available more than one speed of film. The so-called aver-

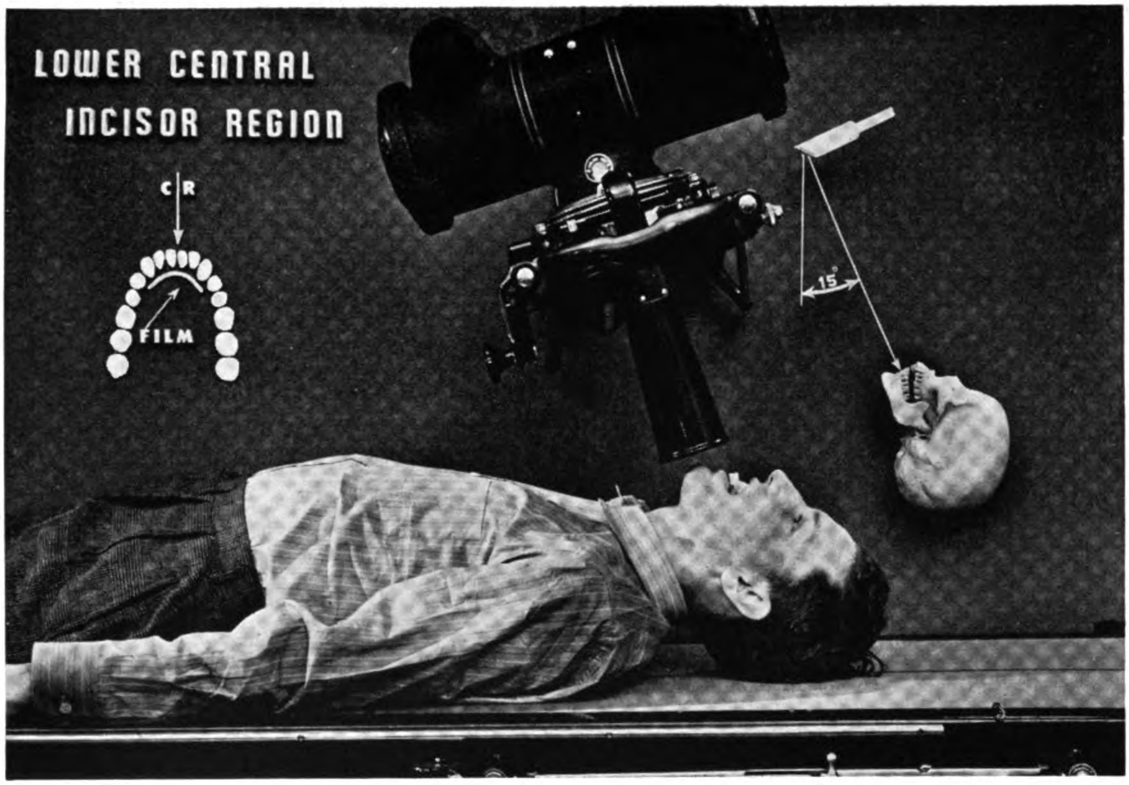


FIG. 368. Position for radiograph of lower central incisor region.

age speed should be used for probably most work, but a much faster film should be used for those occasional cases wherein it is extremely difficult for the patient to hold still.

Lower Central Incisor Region (Figure 368)

The patient is placed in the supine position with the arms at the sides. With the long dimension of the film vertical, both lower corners are curved sharply inward. The film packet is inserted under the tongue and gently adapted to include equally the four incisors. The upper edge of the film is uniformly 3/16 inches above the incisal edges of the teeth. The position of the head is determined by the occlusal plane of the lower teeth which should be vertical to the table top. The tube is tilted 15 degrees toward the patient's head, and the central ray is directed to the gum line at the median line. The central ray must be at right angles to plane of the split angle.

Lower Cuspid Region (Figure 369)

The patient is placed in the supine position with the arms at the sides and with the median line over the table centerline. With the long dimension of the film vertical, the lower mesial corner is curved sharply. The film packet is placed to include the root but not always the entire crown of the lateral incisor, and extends distally. The upper edge of the film is 3/16 inch above the cuspid and the bicuspid occlusal surface. The occlusal plane of the lower teeth should be vertical to the table top. The head is rotated until the cuspid region is directly over the centerline of the table. The tube is tilted 20 degrees toward the patient's head with the central ray centered to the cuspid at the gum line.

Lower First Molar Region (Figure 370)

The patient is placed on the table in the supine position with the median line over the table centerline. If the right side of the jaw is to be radiographed, the right shoulder is elevated by sandbags. With the long dimension horizontal, the lower mesial corner is curved sharply. With the first finger under the lower edge of the film packet to depress the floor of the mouth, the

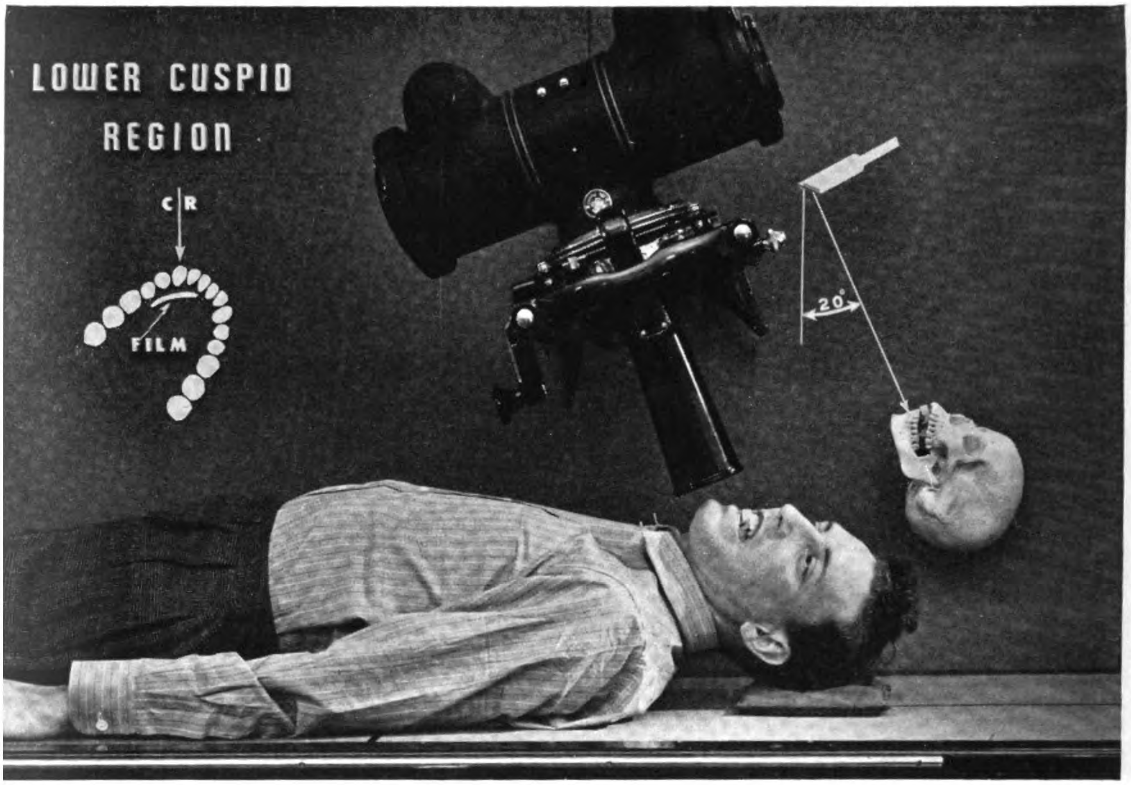


FIG. 369. Position for radiograph of lower cuspid region.

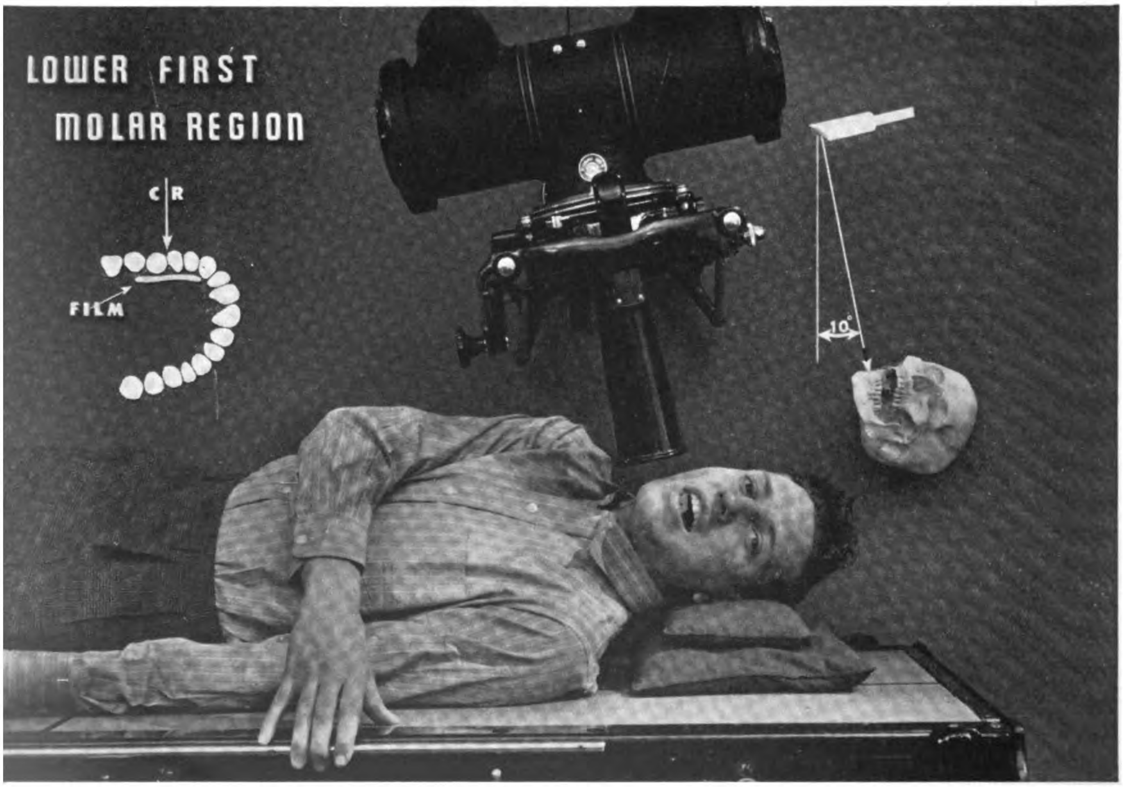


FIG. 370. Position for radiograph of lower first molar region.

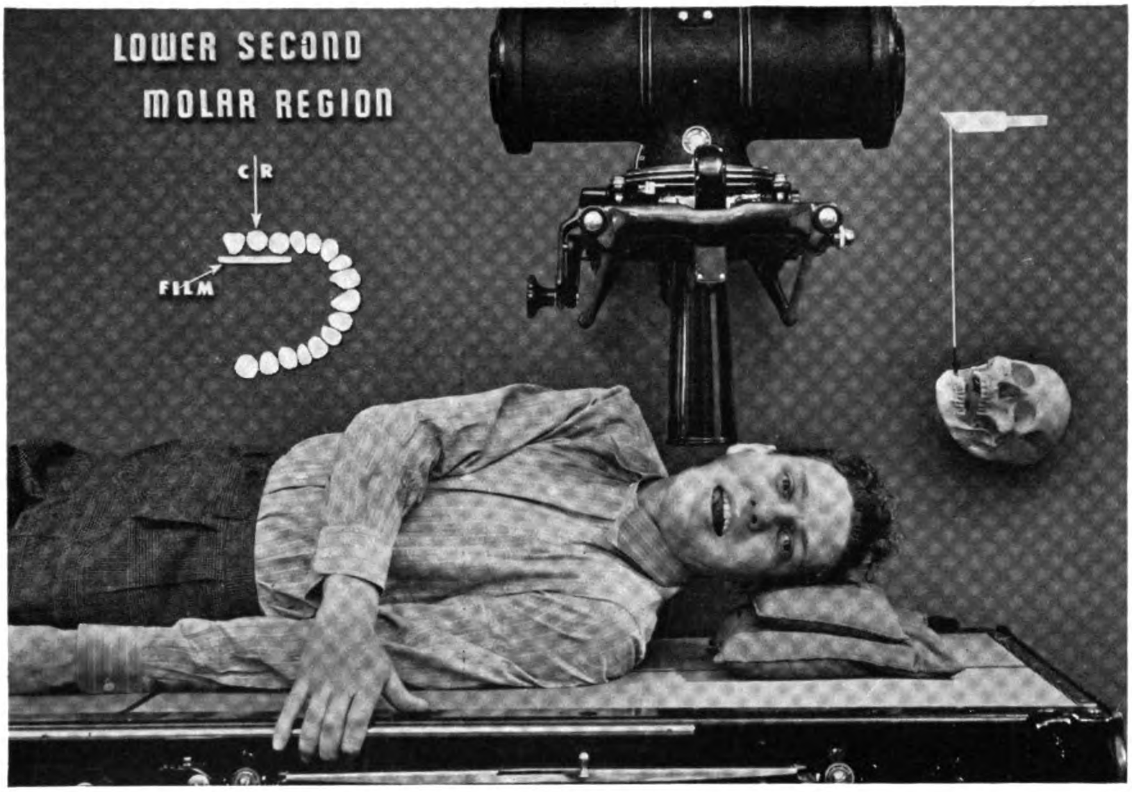


FIG. 371. Position for radiograph of lower second molar region.

film packet is placed so as to include the crown of the cuspid. Then the head is rotated until the region is directly over the table centerline. The occlusal plane of the lower teeth should be vertical to the table top. The tube is tilted 10 degrees toward the patient's head, and the central ray is directed to a point on the gum line between the second bicuspid and first molar.

Lower Second Molar Region (Figure 371)

The patient is placed on the table in the supine position with the median line over the table centerline. If the right side of the jaw is to be radiographed first, the right shoulder is well elevated with sandbags. The film packet, with the first finger under the lower edge of the long dimension in order to depress the tissues, is placed to include the third molar. The head is rotated until the region is directly over the table centerline. The occlusal plane of the lower jaw should be vertical to the table top. No tilt of the tube is required in most instances. The central ray is centered to second molar at the gum line.

Upper Central Incisor Region (Figure 372)

The patient is placed in the prone position with the arms at the sides. With the long dimension of the film vertical, both upper corners are sharply curved. The film is placed in the mouth so as to include equally the four incisors. The upper edge of the film is uniformly 3/16 inch above the incisal edges of the teeth. The position of the head is determined by the occlusal plane, which should be vertical to the table top. The tube is tilted 40 degrees toward the patient's feet and the central ray to the gum line at the median line.

Upper Lateral Incisor Region (Figure 373)

The patient is placed on the table in the supine position with the median line over the table centerline. With the long dimension vertical, sharply curve the upper mesial corner. The film packet is placed to include both central incisors, left or right lateral incisor and cuspid. The upper edge of the film should project 3/16

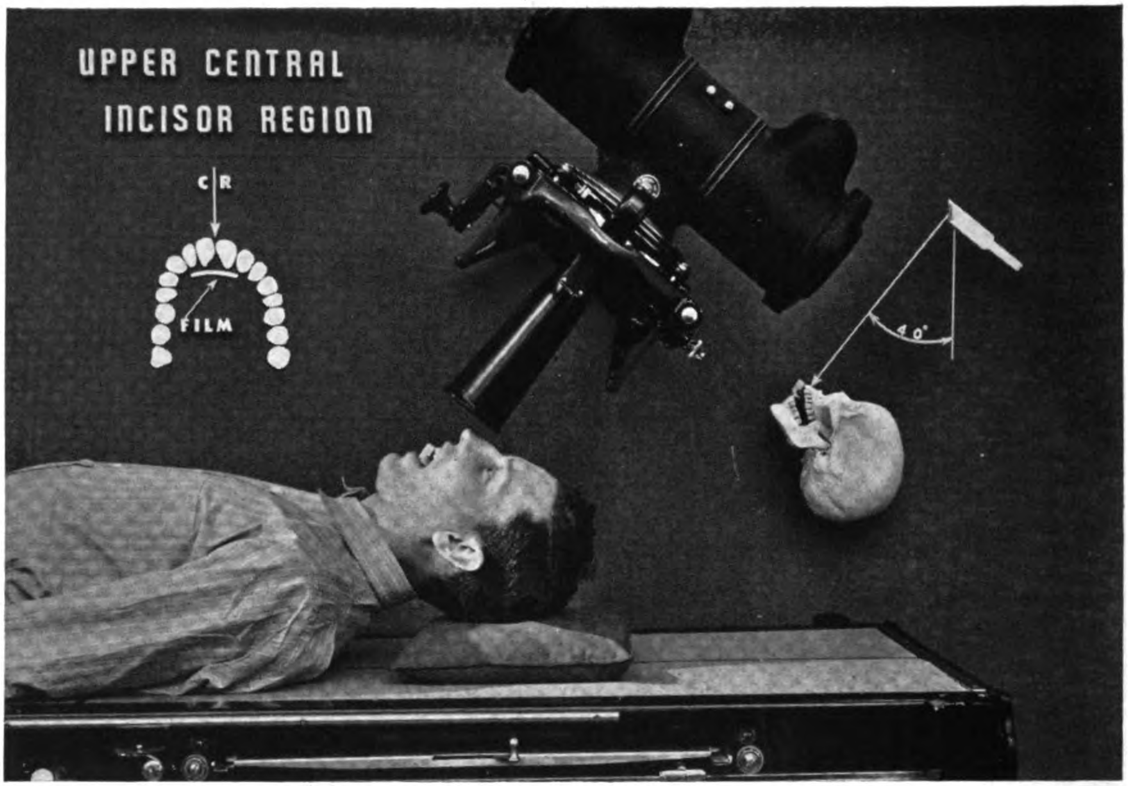


FIG. 372. Position for radiograph of upper central incisor region.

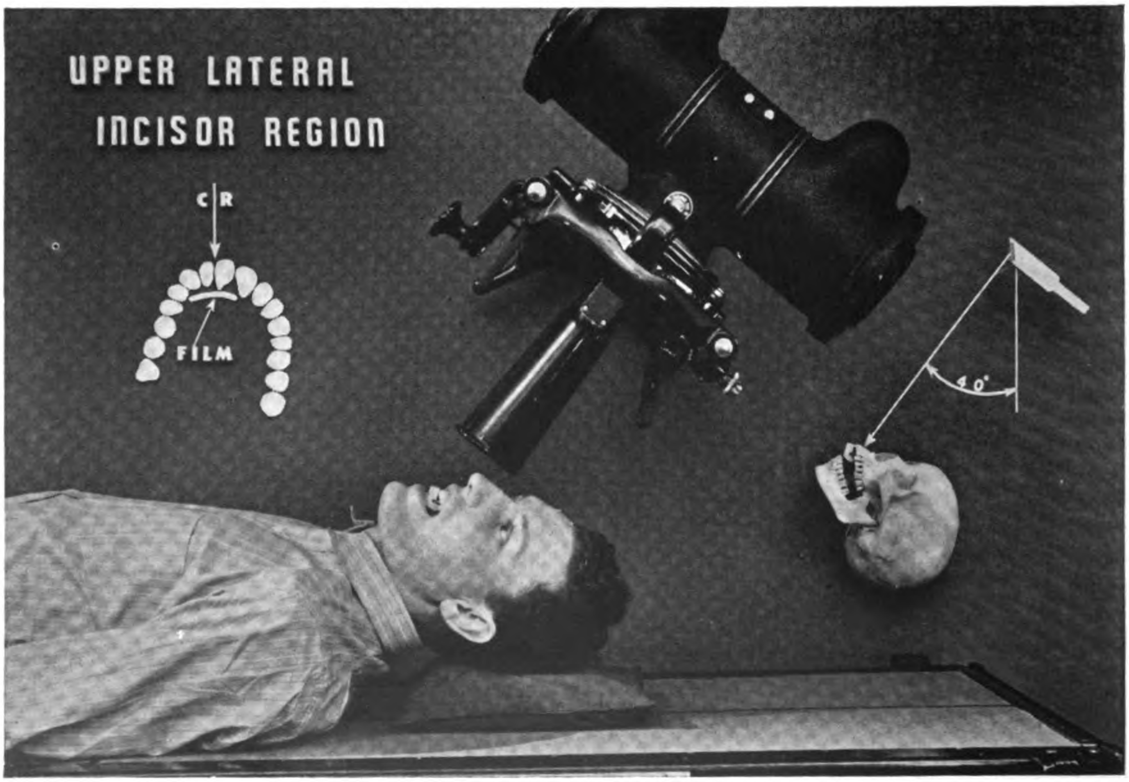


FIG. 373. Position for radiograph of upper lateral incisor region.

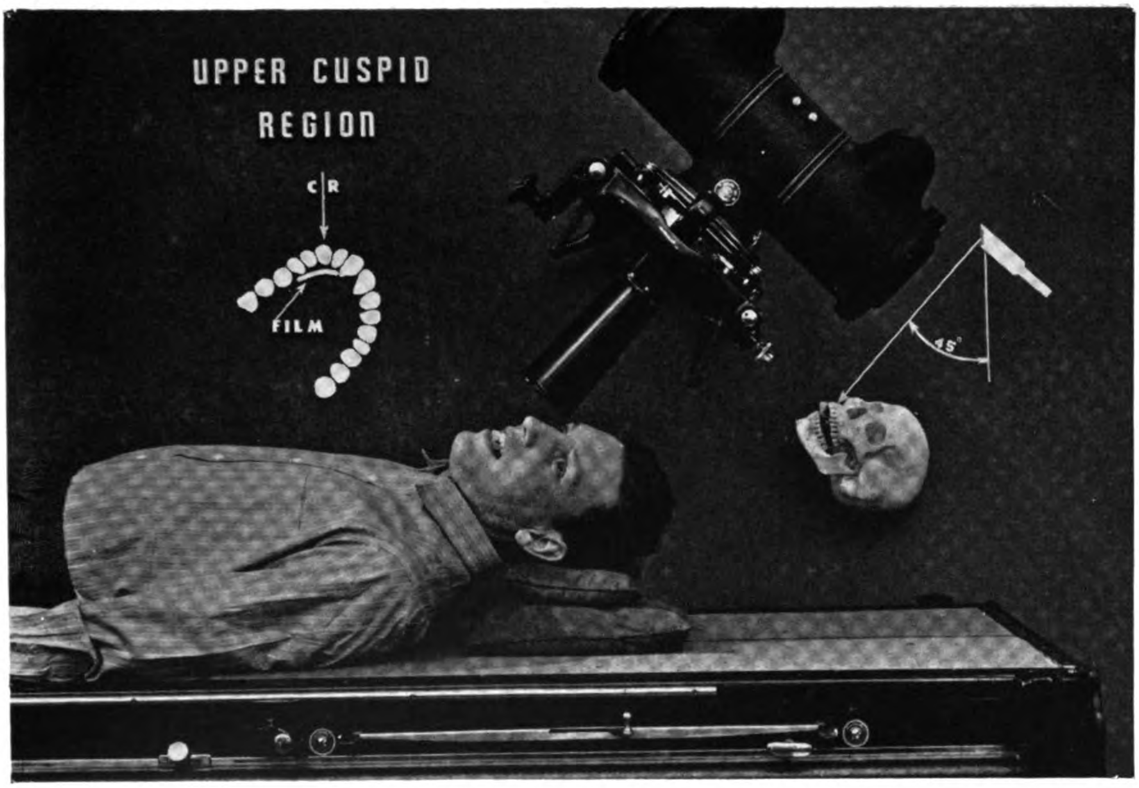


FIG. 374. Position for radiograph of upper cuspid region.

inch beyond the incisal edge of the teeth. The head is rotated until the region being radiographed is directly over the table centerline. The occlusal plane of the upper teeth should be vertical to the table top. The tube is tilted 40 degrees toward the patient's feet and the central ray is directed to a point on the gum line between the central and lateral incisor.

Upper Cuspid Region (Figure 374)

The patient is placed on the table in the supine position with the median line over the table centerline. With the long dimension of the film vertical, the upper mesial corner is curved sharply. The film packet is placed to include the root but not always to include the entire crown of the lateral incisor, and extends distally. The upper edge of the film is 3/16 inch beyond the occlusal surface of the teeth. The head is rotated until the region is directly over the table centerline. The occlusal plane of the upper teeth should be vertical to the table top. The tube is tilted 45 degrees toward the patient's feet and the central ray is centered to the cuspid at the gum line.

Upper First Molar Region (Figure 375)

The patient is placed on the table in the supine position with the median line over the table centerline. If the right side of the jaw is to be radiographed first, the right shoulder is elevated by sandbags. With the long dimension of the film horizontal, the upper mesial corner is curved sharply. The film packet is placed so as to include the crown of the cuspid, and extends laterally. The upper edge of the film extends 1/4 inch beyond the occlusal surface of the teeth. The head is rotated until the region is directly over the table centerline. The occlusal plane should be vertical to the table top. The tube is tilted 30 degrees toward the patient's feet and the central ray is directed to a point on the gum line between the second bicuspid and first molar.

Upper Second Molar Region (Figure 376)

The patient is placed on the table in the supine position with the median line over the table centerline. If the right side is to be radiographed first, the right shoulder is elevated first. With

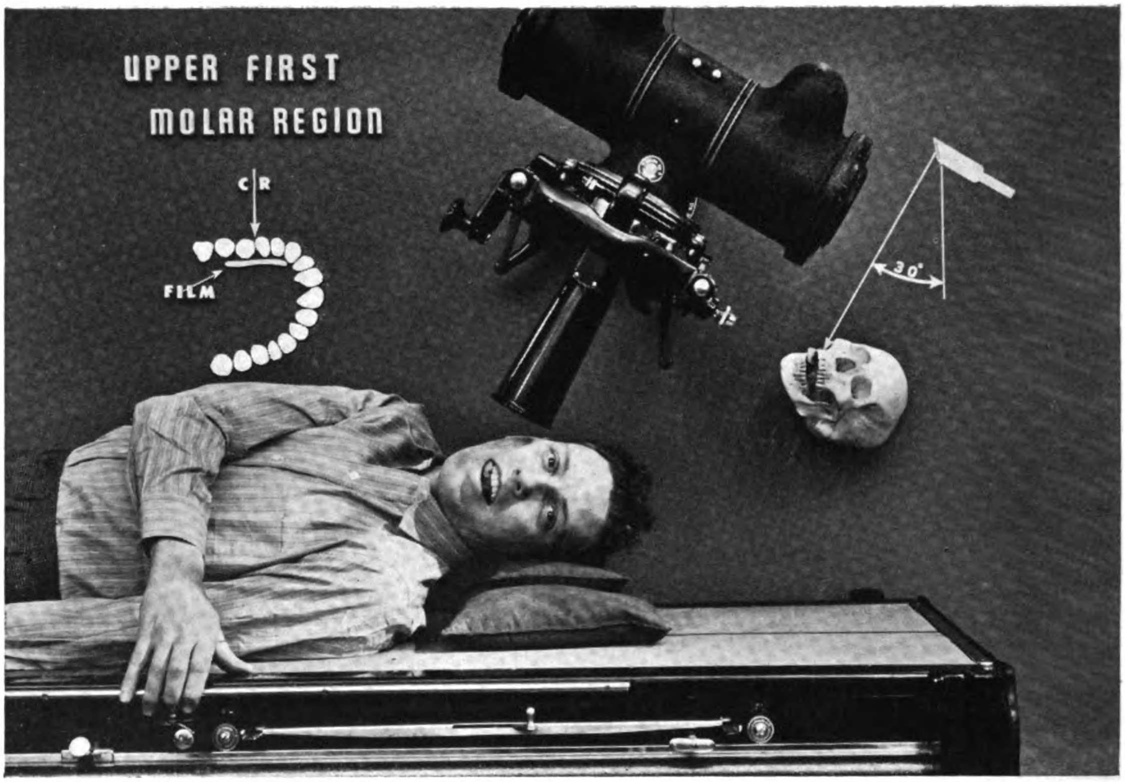


FIG. 375. Position for radiograph of upper first molar region.

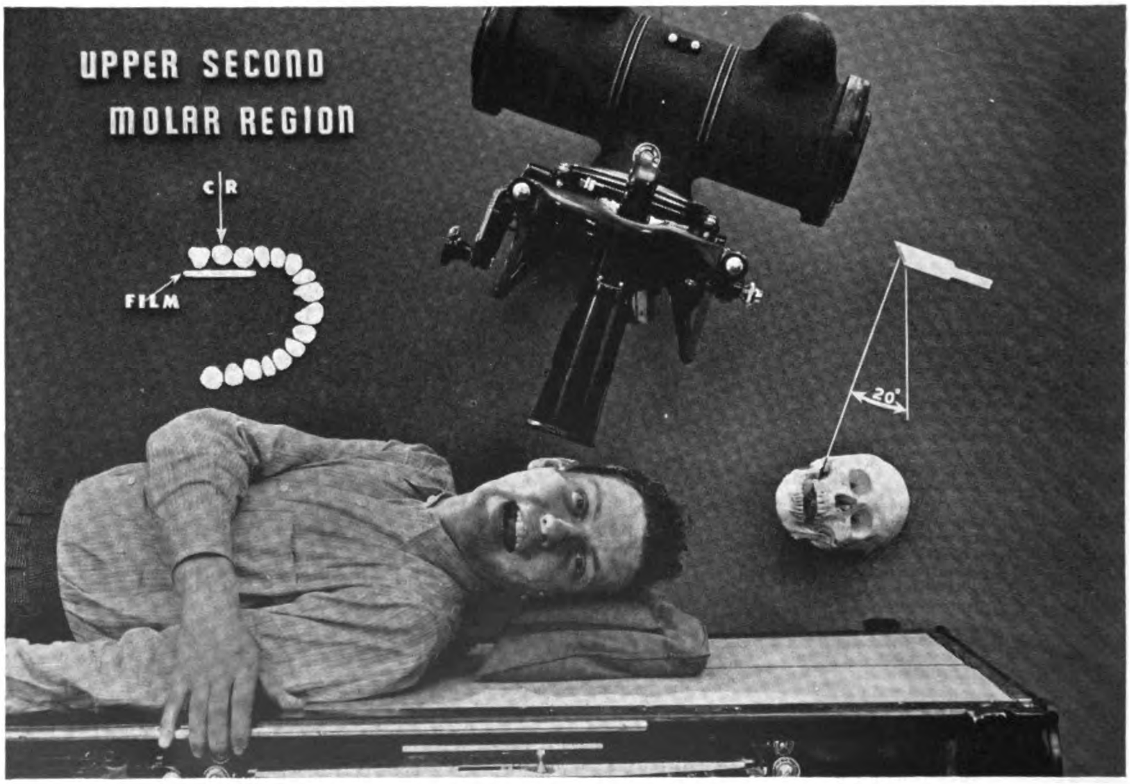


FIG. 376. Position for radiograph of upper second molar region.

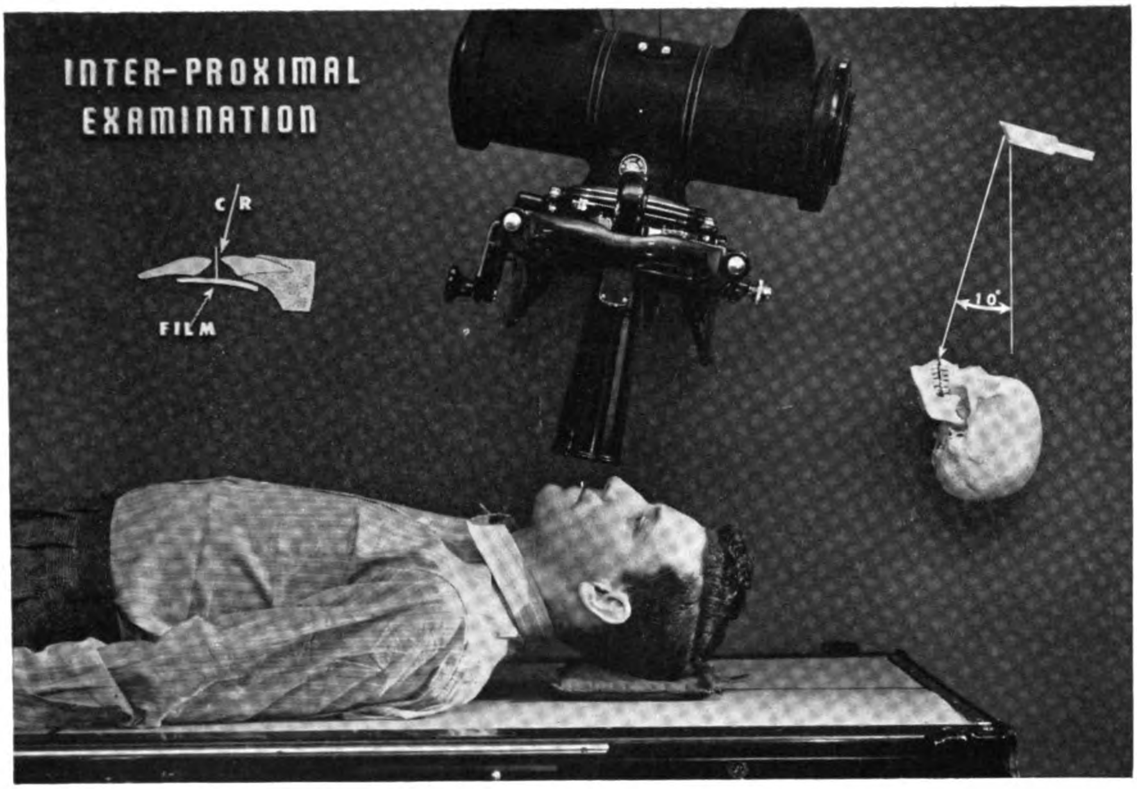


FIG. 377. Position for radiograph of inter-proximal examination.

the long dimension horizontal, the upper distal corner of the film is curved sharply. The film is placed so as to include the third molar and extends mesially. The upper edge of the film extends ¼ inch beyond the occlusal surface of the teeth. The head is rotated until the region is directly above the median line. The occlusal plane of the upper teeth should be vertical to the table top. The tube is tilted 20 degrees toward the patient's feet and the central ray is centered to the second molar at the gum line.

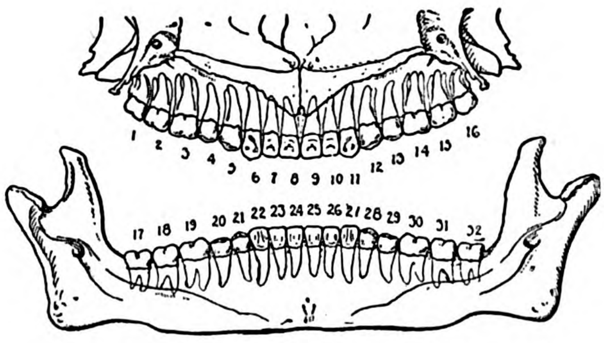
Inter-Proximal Examination (Figure 377)

The patient is placed on the table in the supine position with the occlusal plane vertical to the table top. The corners of the film pack are sharply curved, and then inserted so that the bite-wing is parallel to the occlusal plane. The tube is tilted 10 degrees toward the patient's feet with central ray directed to the occlusal plane.

Figure 378 gives the name and location of each tooth in the adult mouth.

UPPER

1. Upper left 3rd molar
2. Upper left 2nd molar
3. Upper left 1st molar
4. Upper left 2nd bicuspid
5. Upper left 1st bicuspid
6. Upper left cuspid
7. Upper left lateral incisor
8. 9. Upper central incisors
10. Upper right lateral incisor
11. Upper right cuspid
12. Upper right 1st bicuspid
13. Upper right 2nd bicuspid
14. Upper right 1st molar
15. Upper right 2nd molar
16. Upper right 3rd molar



LOWER

17. Lower left 3rd molar
18. Lower left 2nd molar
19. Lower left 1st molar
20. Lower left 2nd bicuspid
21. Lower left 1st bicuspid
22. Lower left cuspid
23. Lower left lateral incisor
24. 25. Lower central incisors
26. Lower right lateral incisor
27. Lower right cuspid
28. Lower right 1st bicuspid
29. Lower right 2nd bicuspid
30. Lower right 1st molar
31. Lower right 2nd molar
32. Lower right 3rd molar

FIG. 378. Diagram showing location of each tooth.

Photography of the Fluorescent Screen Image

The idea of photographing the fluorescent screen image is almost as old as the discovery of x-rays. A great many experiments have been conducted in various parts of the world in an attempt to successfully photograph the fluoroscopic image direct from the fluorescent screen.

In general, most of these experiments have been directed toward the making of moving pictures of those areas of the body which are affected by involuntary motion, such as the chest, heart, stomach, etc. Because of the many limitations, however, it was not until recent years that such work could be done successfully.

The results obtained with motion pictures focused attention on other fields, principally so-called miniature radiography for group surveys through the utilization of single exposures instead of motion pictures.

The object of such a development was to find a more economical, yet efficient, means for conducting group examinations of the chest.

Several sizes of so-called miniature films have been employed at various times, from the so-called 35 mm film, up to the more recent development, the 4- by 5-inch film.

It is not the purpose here to discuss the relative merits of various sizes of miniature chest films, but rather to describe the apparatus in general from a technical standpoint.

Various names for this type of work have gradually evolved: *Fluorography,* which ordinarily refers to the use of 35 mm film; and *photoroentgenography,* which refers to the use of 4- by 5-inch film.

Regardless of the size of film, the basic principle of the apparatus is essentially the same.

Figure 379 is a line drawing of photo-roentgen equipment. From this it will be seen that it is composed of a light-tight housing, at one end of which is a fluorescent screen and at the other end a camera and film shifter for stereoscopy. The camera and shifter here shown are for paired 4- by 5-inch stereos, on a single 4- by 10-inch film.

The fluorescent screen is mounted with the fluorescent side toward the camera. The size of the screen is usually 14- by 17-inches, the same as

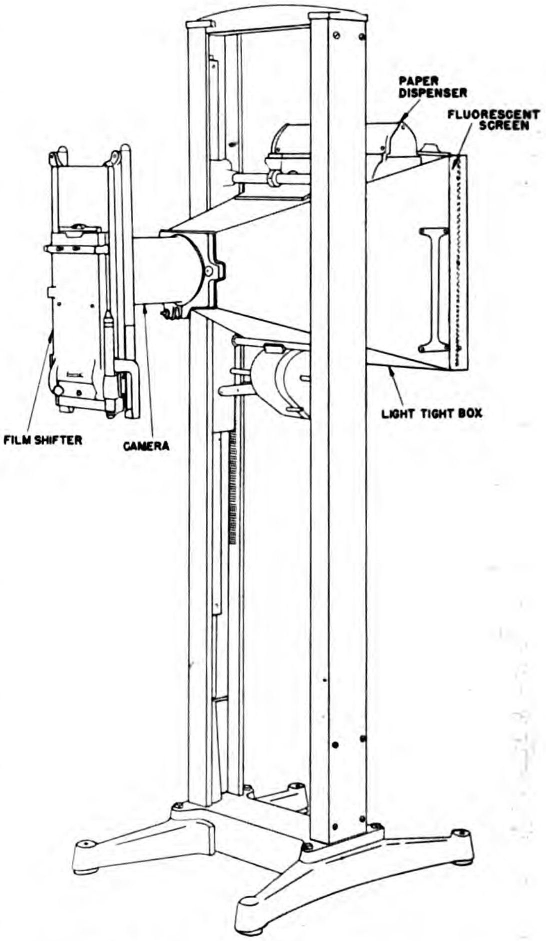


Fig. 379. Line drawing of photo-roentgen unit.

would be employed when doing direct radiography of the chest.

The fluorescent screen generally employed for 35 mm fluorography is a standard type B Patterson fluoroscopic screen.

The fluorescent screen used with the 4- by 5-inch film is made specially for photo-roentgenography. The fluorescent light given off by the Patterson model B type fluoroscopic screen is in the yellow-green portion of the spectrum. The fluorescent light given off by the special photo-roentgen screen is in the blue-violet portion of the spectrum.

The lenses employed for this procedure must be exceedingly fast. A speed of F 1.5 is generally used. The reason for this speed is the necessity for keeping x-ray energy within practical limits.

In practice, there is little actual difference in operative procedure between photo-roentgenography and regular radiography of the chest. In the case of the 4- by 5-inch film, a light-tight film holder is loaded, two films to the holder, one on either side. For the smaller films, roll films are employed.

As previously mentioned, the housing is light-tight; therefore, the conventional camera shutter is not necessary; if the camera happens to be so equipped, the shutter is simply left open.

The patient is placed in position, figure 380, the tube is centered in the usual manner, and the exposure is made by the regular x-ray timer.

The camera obviously must be focused to the screen surface to provide for maximum detail and, since the lens-screen distance remains constant, it is not necessary to refocus the camera once it is correctly set.

During the x-ray exposure, the chest image will appear on the screen, and it is this image which is photographed at the reduced size. Actual comparison of sizes is found in figures 381 and 382.

Several types of films are employed. If the Patterson type B screen is used, a green-sensitive

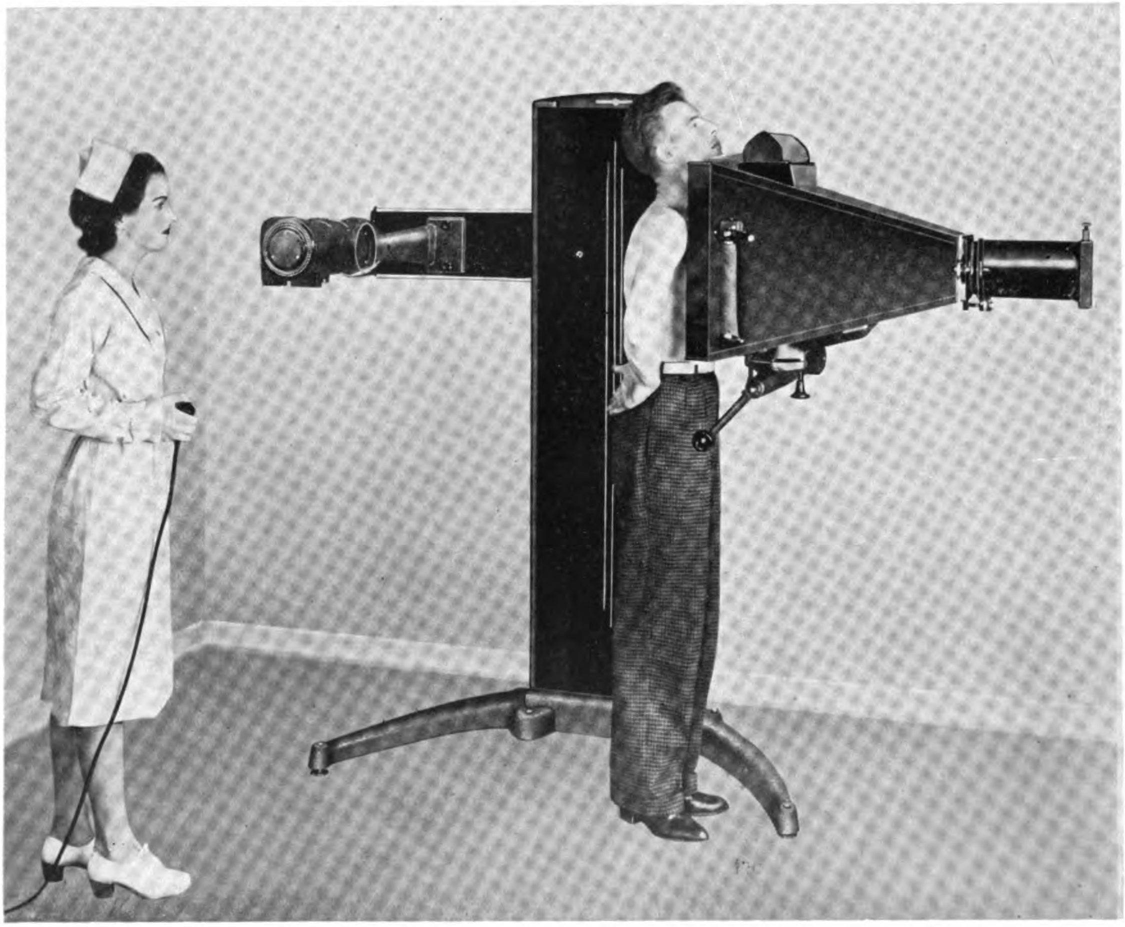


FIG. 380. Patient in position for photo-roentgenogram.

film is necessary. If the Patterson photo-roentgen screen is used, which fluoresces in the blue-violet portion of the spectrum, films most sensitive to this fluorescence are employed. Inasmuch as the special photo-roentgen screen for the 4- by 5-inch film is actually an x-ray intensifying screen, regular double-coated x-ray film, the same as is employed in regular radiography, proves quite satisfactory from the standpoint of speed and contrast.

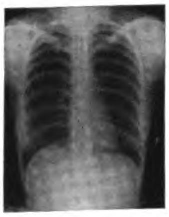


FIG. 381. 35 mm. result, actual size.

The processing of the blue-sensitive film is obviously and naturally the same as for regular x-ray film, because it is either the same film as used for regular radiography with intensifying screens, or even in the case of special film possesses the same characteristics.

Blue-sensitive film, coated on one side only, is also available. Being a single-coated film, there is an improvement in detail sharpness in comparison with the double-coated film. The reason for this is that actually an appreciable percentage of the total density of the double-coated film is on the back emulsion.

A marked improvement in diagnostic quality results when a stationary Bucky grid is employed in photo-roentgenography. The use of the grid materially improves visibility of detail and also adds to the latitude insofar as operative technic is concerned as between various sizes of individuals. When the stationary grid is employed for chest work with a 14- by 17-inch film, the images or shadows of the grid are, of course, visible; on the contrary, when employed in photo-roentgenography, they are not visible to the eye.

Not only are miniature films made in single exposures, but stereoscopically as well, the latter method being considered by most diagnosticians as the one of choice.

In the case of the 35 mm film, both single and stereoscopic, it is necessary to magnify the image considerably, this being necessary for diagnosis.

The 4- by 5-inch stereoscope, for viewing paired 4 by 5 films on a single 4 by 10 film, is an ingenious combination of prisms and lenses so arranged that no adjustment is necessary except for inter-pupillary distance. It is known as an Ortho-stereoscope because of the truthfulness of rendition of the stereoscopic effect. The entire optical system is so designed that minimum eyestrain results. This is of special importance where many hundreds of films must be viewed within a comparatively short time.

The energy values employed are greater than for regular radiography, but in all cases well within the rated limits of available generators and x-ray tubes.

Miniature radiography can no longer be considered in its infancy. Evaluated on the basis of the purpose for which it is intended, it is due to have a far-reaching effect in providing for a more economical and efficient means for group surveys of the chest, thereby making still more effective the world-wide efforts directed toward the control of tuberculosis.

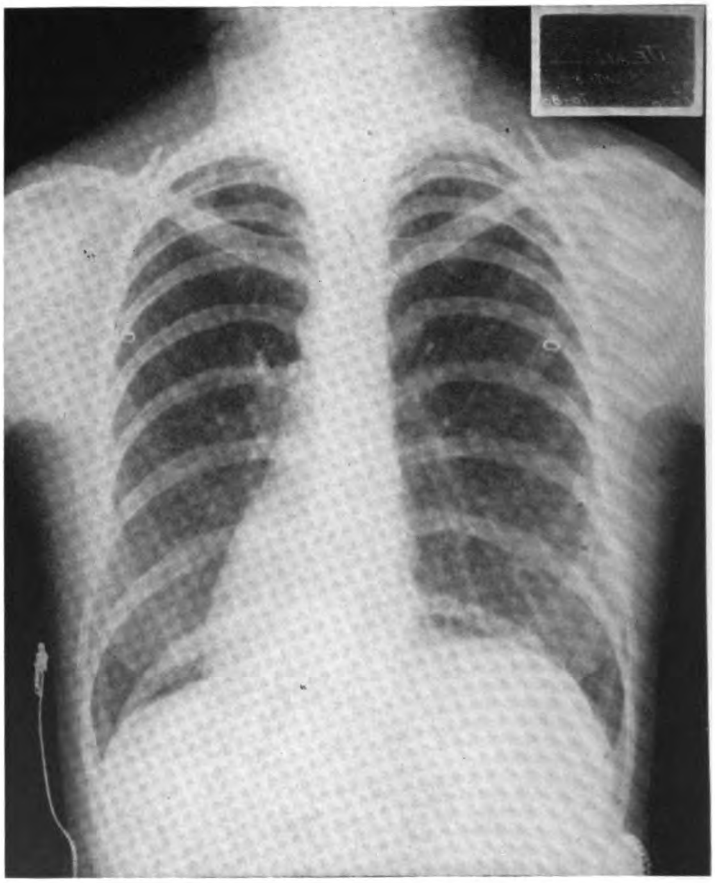


FIG. 382. 4- x 5-inch result, actual size.

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THIS BOOK

MEDICAL
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Third Printing

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